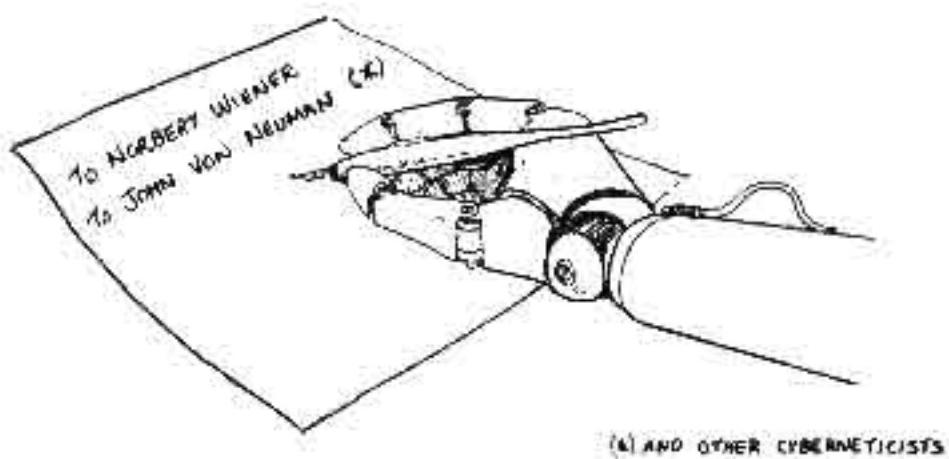
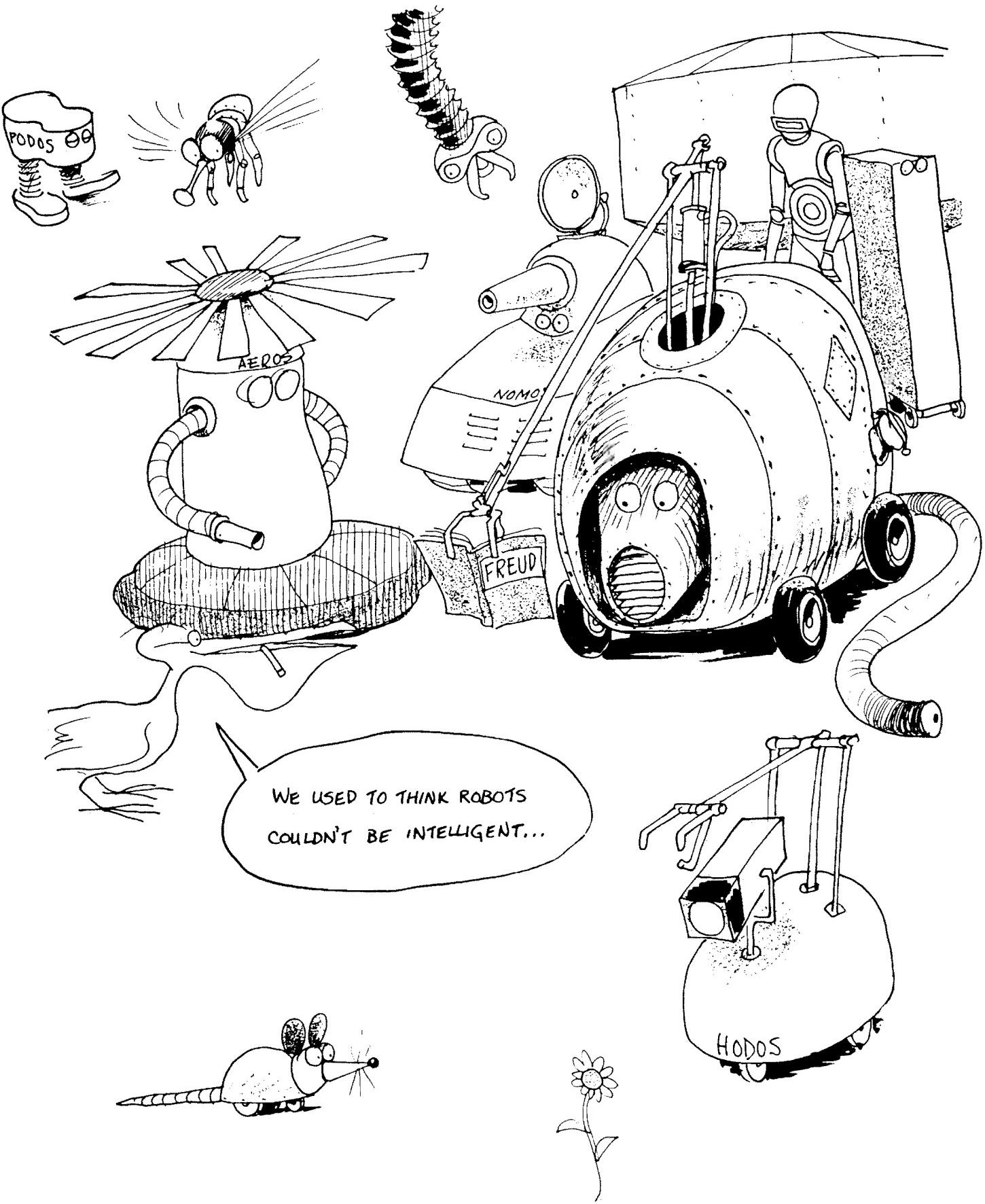


**The Adventures of  
ARCHIBALD HIGGINS**

# **RUN, ROBOT, RUN**

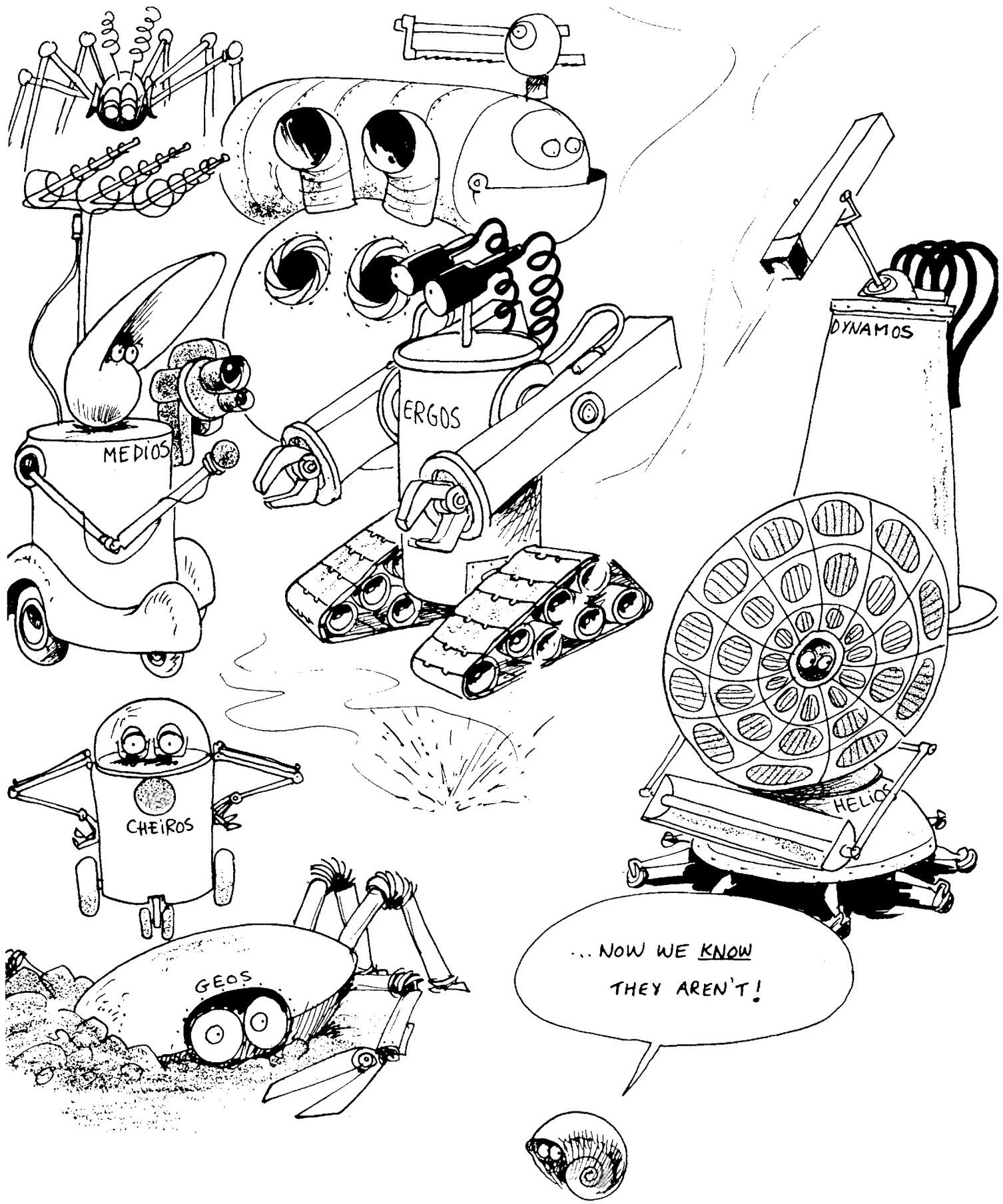
**Jean-Pierre Petit**





WE USED TO THINK ROBOTS  
COULDN'T BE INTELLIGENT...

HODOS



The Association Knowledge without Borders, founded and chaired by Professor Jean-Pierre Petit, astrophysicist, aims at spreading scientific and technical knowledge in as many countries as possible and in as many languages as possible. To this end, all his popular scientific works, which cover a period of thirty years, and more particularly the illustrated albums he has created, are now freely accessible. Anyone is now free to duplicate the present file, either in digital form or in the form of printed copies and circulate these copies to libraries , within the context of schools or universities or associations whose aims would be the same as the association , provided that they do not derive any profit from this circulation and that they do not have any political, sectarian or confessional connotations. These pdf files may also be put on line in the computer networks of school and university libraries.



Jean-Pierre Petit intends to create numerous other works which will be accessible to a larger audience. Even illiterate people will be able to read them because the written parts will "speak" when the readers click on them. Thus it will be possible to use these works to support literacy schemes. Other albums will be "bilingual" in so far as it will be possible to switch from one language to another selected language with a mere click. Hence another tool made available to develop language skills.

Jean-Pierre Petit was born in 1937. He made his career in French research. He worked as a plasma physicist, he directed a computer science centre, he has created softwares, he has published hundreds of articles in scientific magazines, dealing with subjects ranging from fluid mechanics to theoretical cosmology. He has published about thirty books which have been translated in numerous languages.

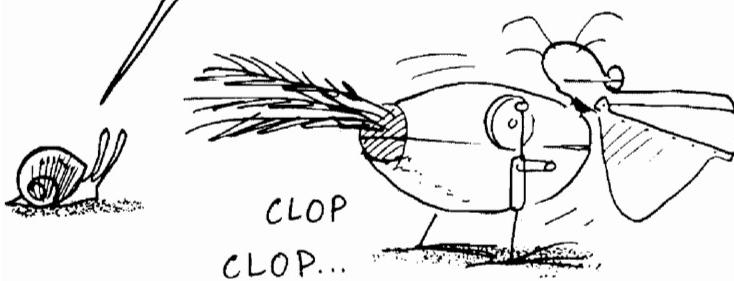
The association can be contacted on the following internet site:

**<http://savoir-sans-frontieres.com>**

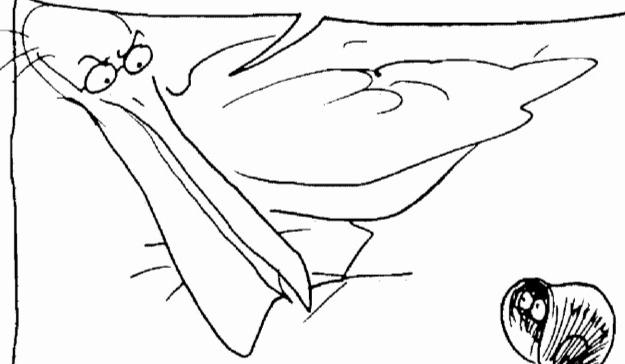
# PROLOGUE



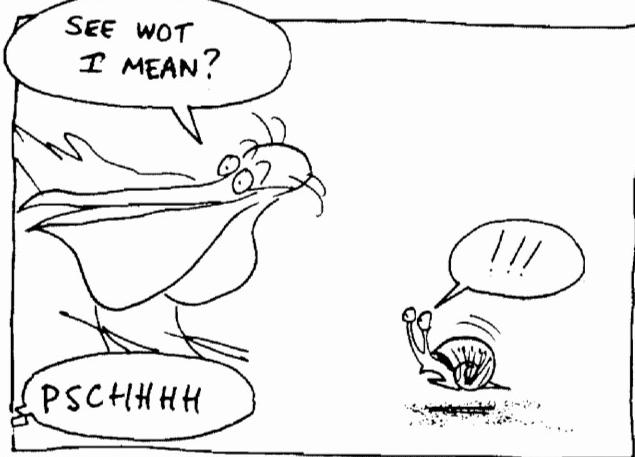
LOOKIT, LOOKIT!  
IT WALKS!



OH, STUFF IT, TIRESIAS!  
ONE O' THESE DAYS YER'LL  
BE LAUGHIN' ON THE UVVER  
SIDE O' YER BLINKIN' FACE!

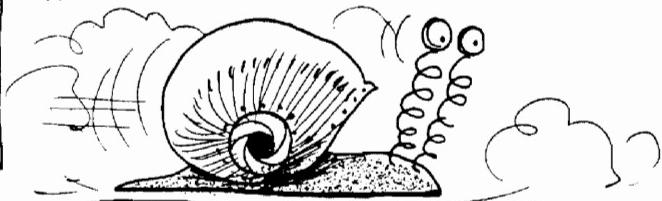


SEE WOT  
I MEAN?

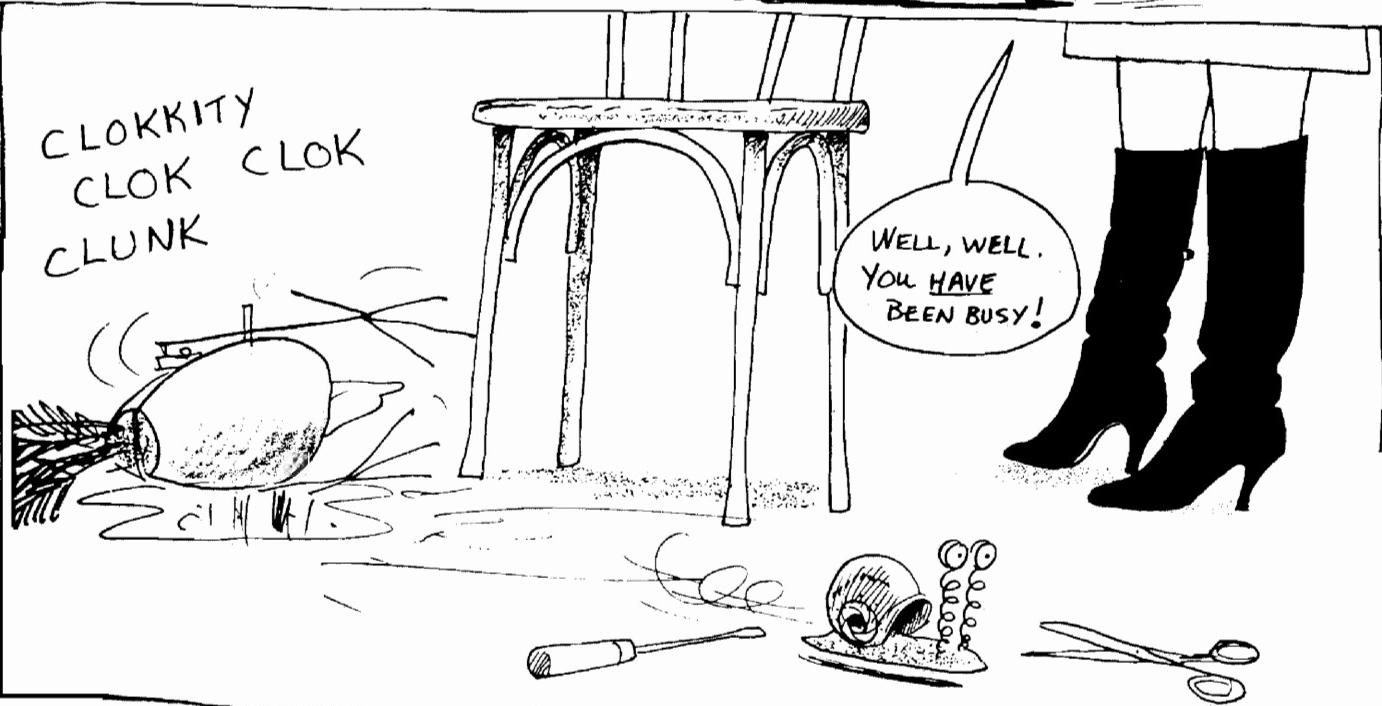


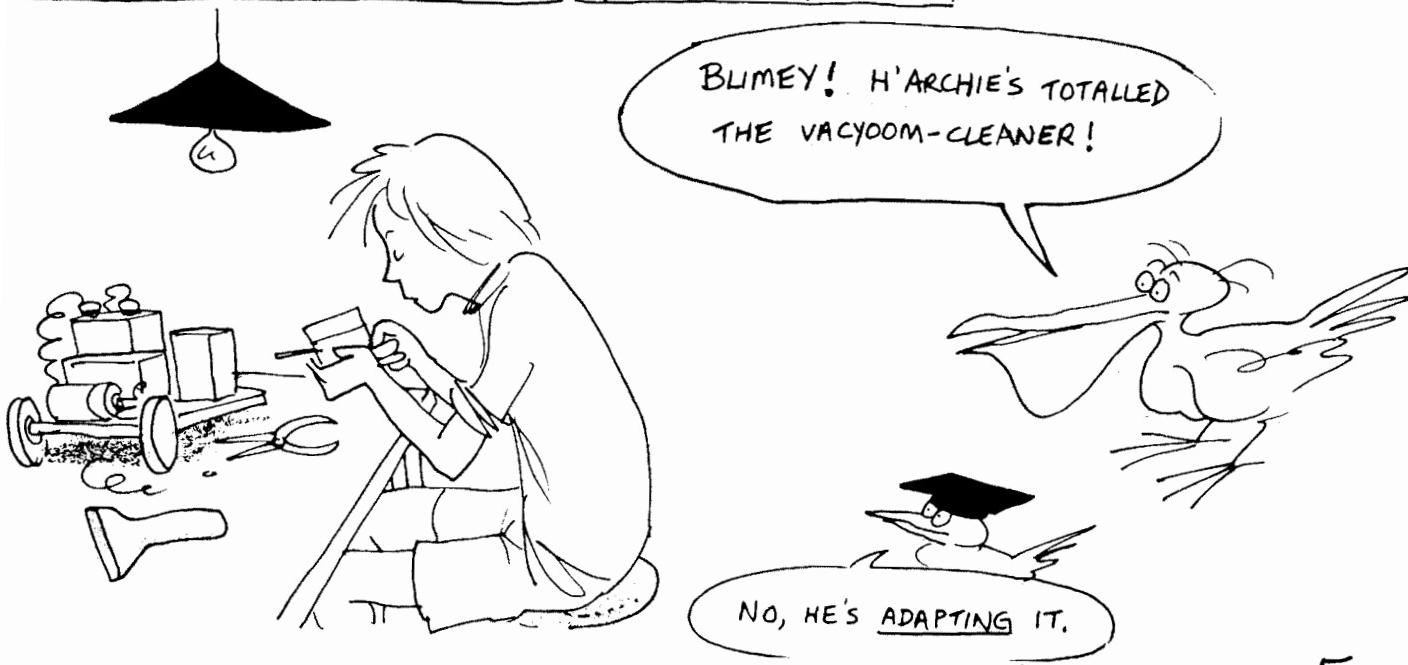
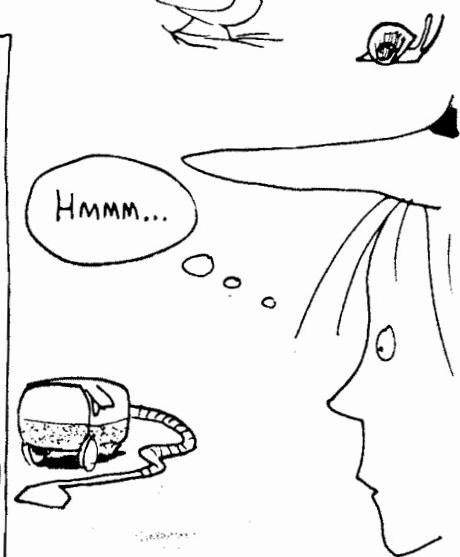
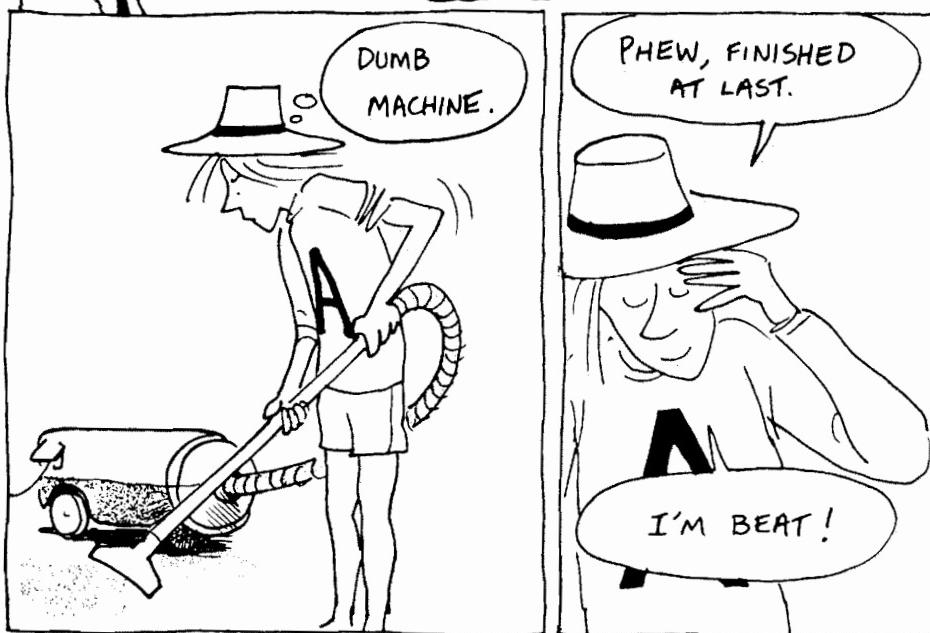
A HOVERSNAIL ON  
AN AIR-CUSHION!

WHOOOARRR

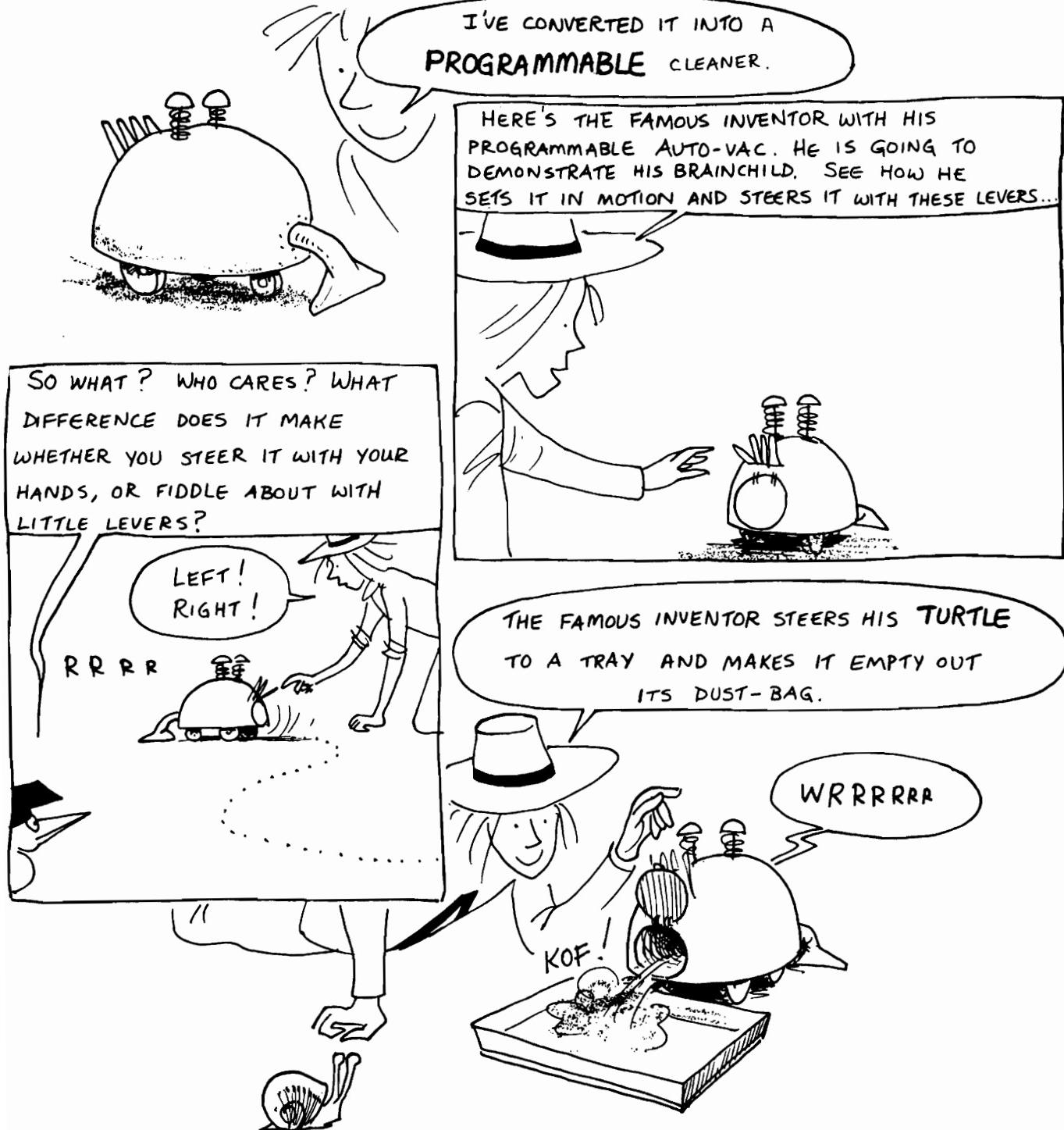


CLOKKITY  
CLOK CLOK  
CLUNK

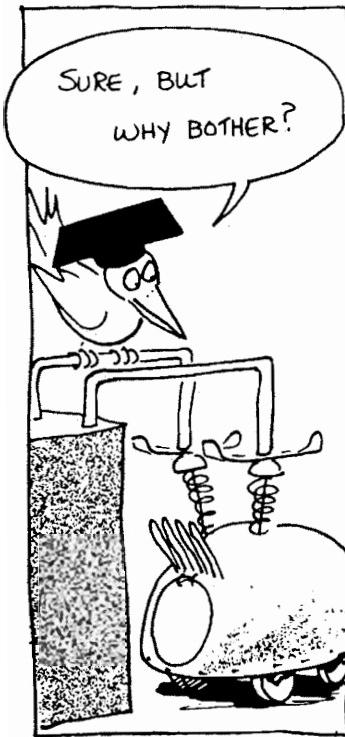
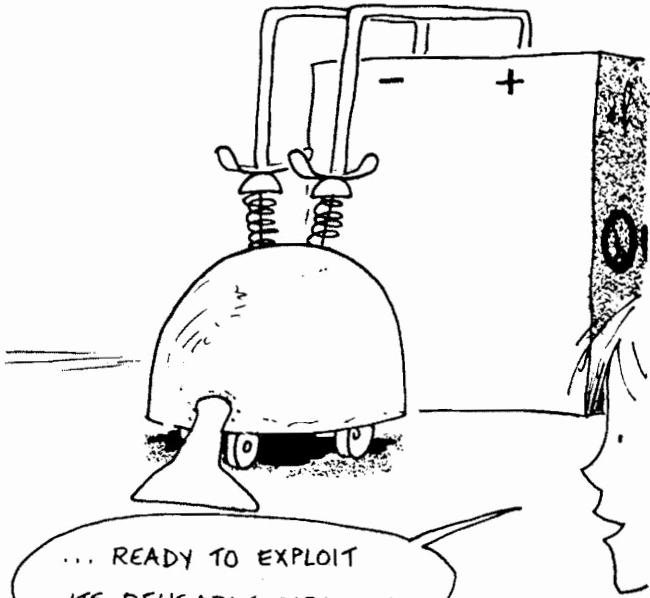
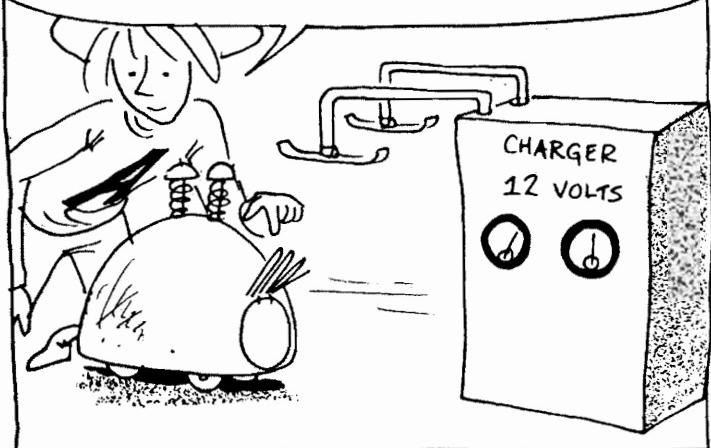


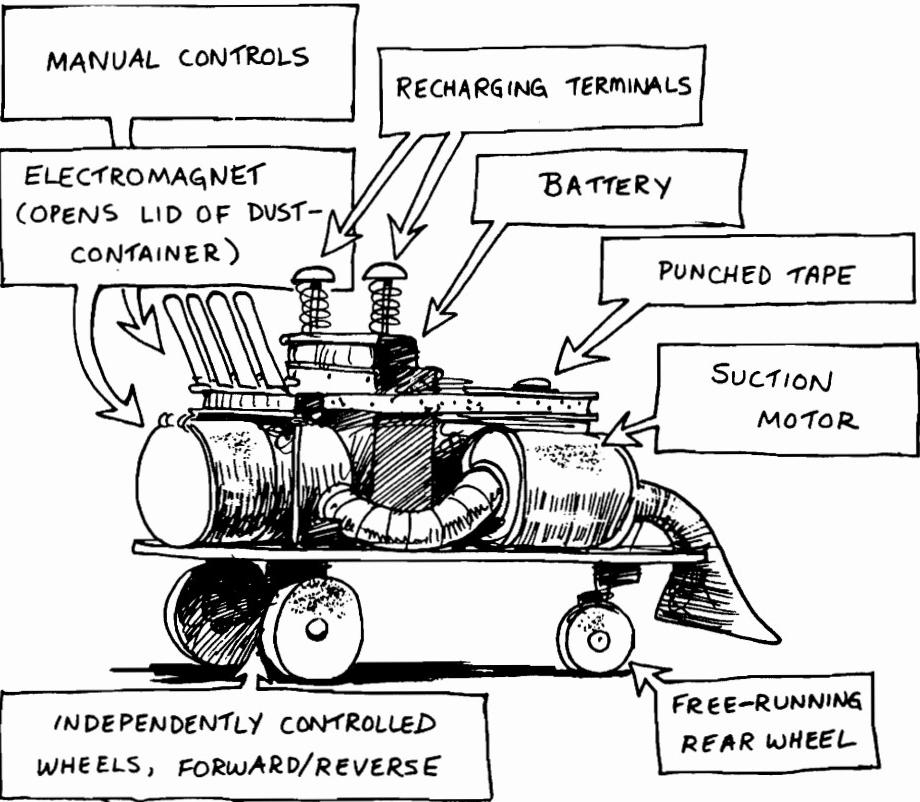
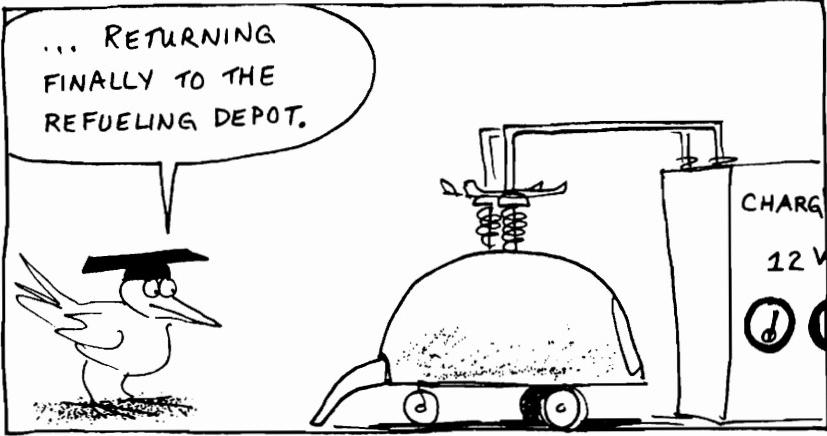
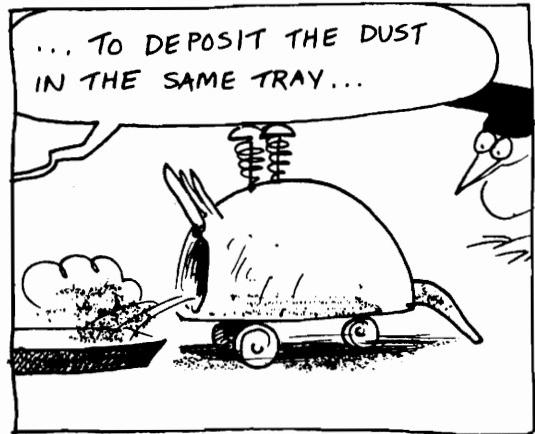


# PROGRAMMABLE AUTOMATA



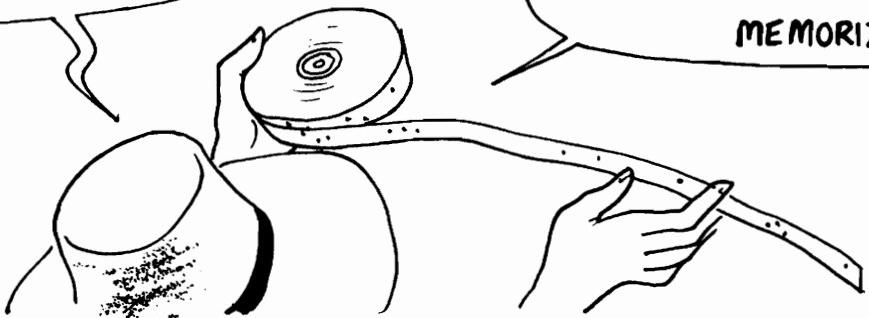
THE JOB DONE, HE DIRECTS IT TO THE  
FUEL-CELL REPOWERING MODULE...

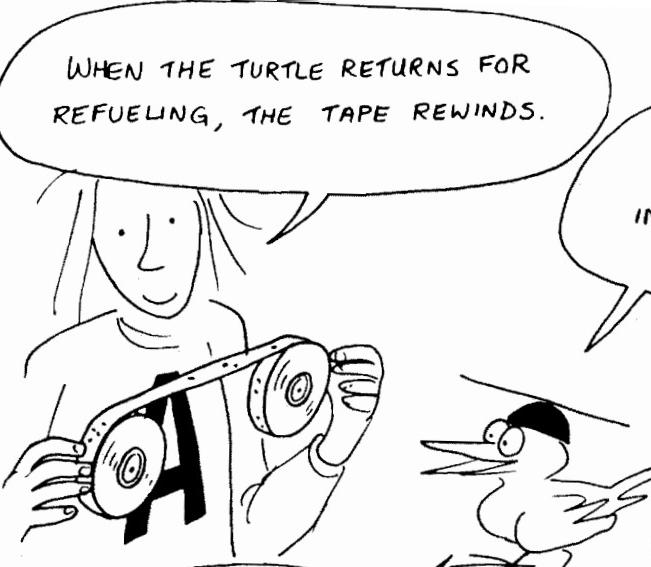




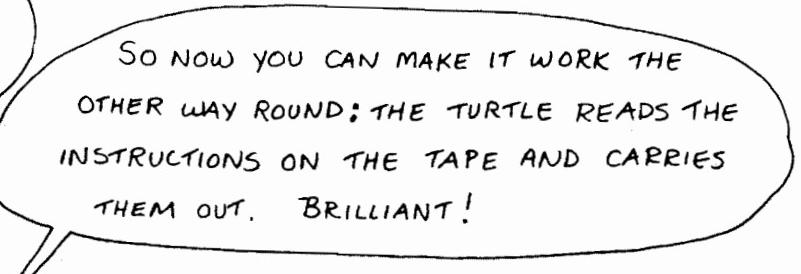
WHEN I OPERATED THE  
TURTLE MANUALLY, THIS  
TAPE UNWOUND AT A STEADY RATE.  
THE COMMANDS THAT I GAVE IT  
WERE WRITTEN ON TO THE TAPE IN  
THE FORM OF PUNCHED HOLES.

SO THE STEPS INVOLVED IN  
THE JOB WERE ALL  
MEMORIZED.



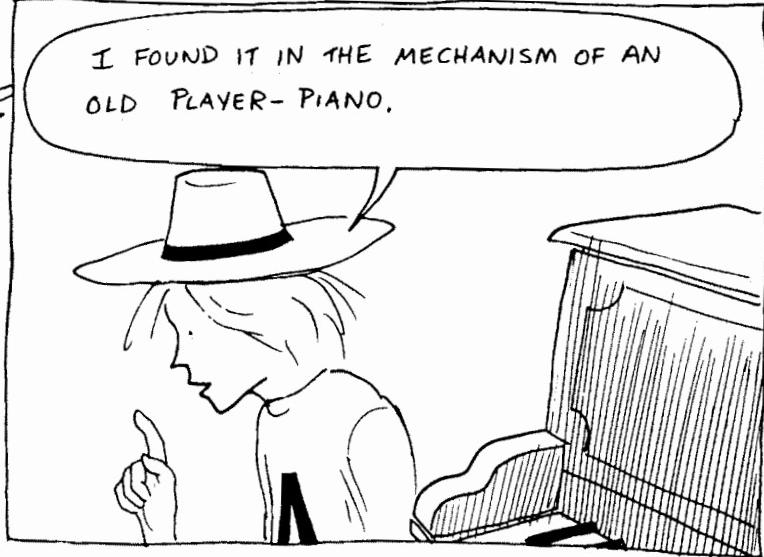


WHEN THE TURTLE RETURNS FOR  
REFUELING, THE TAPE REWINDS.



SO NOW YOU CAN MAKE IT WORK THE  
OTHER WAY ROUND: THE TURTLE READS THE  
INSTRUCTIONS ON THE TAPE AND CARRIES  
THEM OUT. BRILLIANT!

WHERE DID YOU  
GET THAT?



I FOUND IT IN THE MECHANISM OF AN  
OLD PLAYER-PIANO.

!?

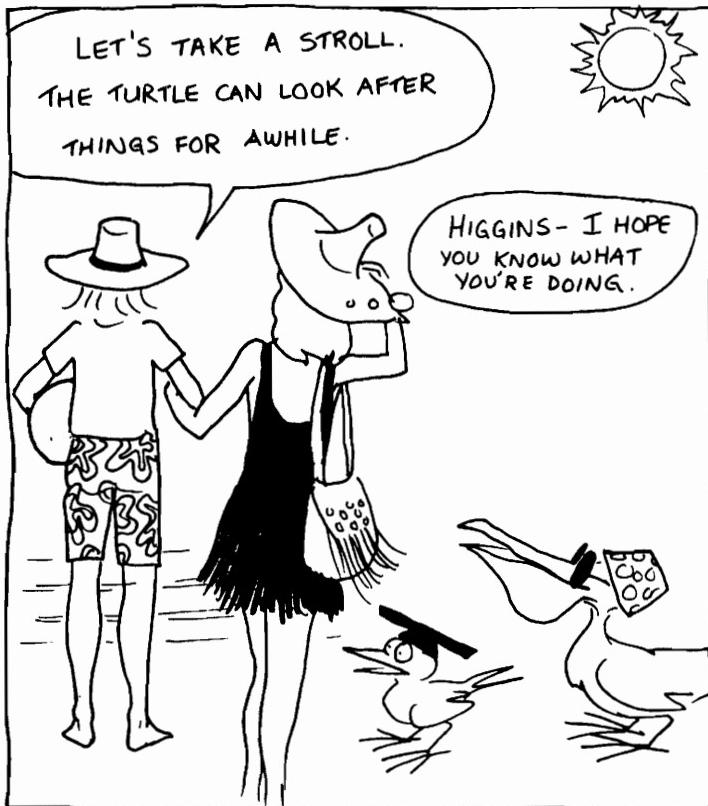


THE DINING-ROOM  
VACUUM STAKES,  
THIRD RACE!

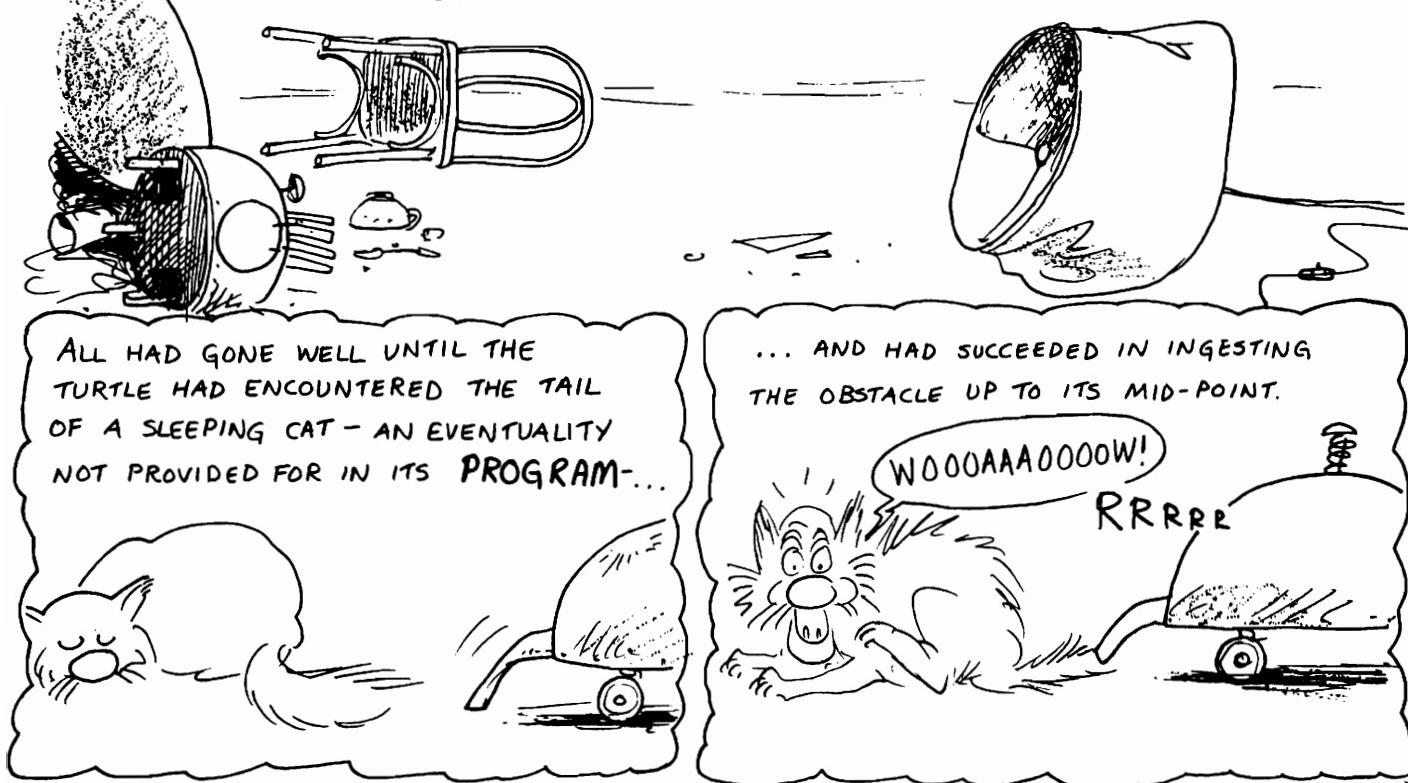
THE FLAG IS  
RAISED... THEY'RE  
OFF!

OH OH,  
OBSTRUCTION ON THE  
TRACK! LOOK OUT,  
SOPHIE!

R R R R R



THE MARVELS OF MODERN  
FORENSIC SCIENCE ALLOW US TO  
RECONSTRUCT THE SEQUENCE  
OF EVENTS...



SPLING!

DURING THE ENSUING PANIC, THE CAT DRAGGED THE VACUUM-CLEANER TURTLE THE LENGTH OF THE APARTMENT, CAUSING A CERTAIN AMOUNT OF INCIDENTAL DAMAGE.

BONK!

TIM-BERRR!

THE BATTERY ACID HAS SPILT AND EATEN HOLES IN THE RUG.

AND THE CONFOUNDED TURTLE'S EATEN MY KNITTING!

I KNOW... I KNOW... I'LL MAKE SURE IT'S ALL CLEANED UP.

PFFFFT

CLIP!

THE CAT LEFT A MESSAGE.

"I'M NOT STAYING A  
MOMENT LONGER IN THIS  
NUTHOUSE. DON'T COUNT ON ME  
TO CATCH YOUR MICE. GOODBYE  
AND GOOD RIDDANCE."

BUT HE DIDN'T  
GIVE HIS NOTICE!

I THOUGHT MY TURTLE WAS  
INTELLIGENT, BUT NOW I SEE HOW  
DUMB IT WAS.

# INPUT-OUTPUT SYSTEMS

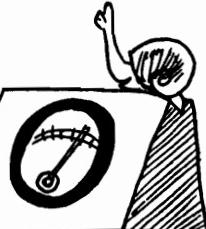
HOW DID YOU THINK IT COULD BE INTELLIGENT?  
YOU GAVE IT NO WAY OF KNOWING WHAT WAS GOING  
ON AROUND IT!

YOU'RE RIGHT. THE TURTLE NEEDS TO "SEE"  
WHERE IT'S GOING. THIS IS A TINY PHOTOCELL  
SENSITIVE TO INFRARED LIGHT - THAT IS,  
THERMAL RADIATION.

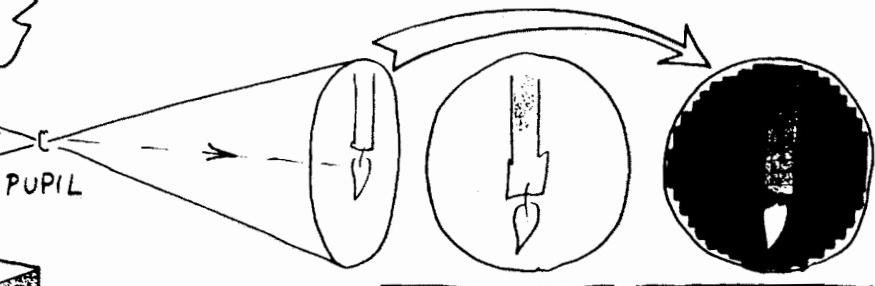
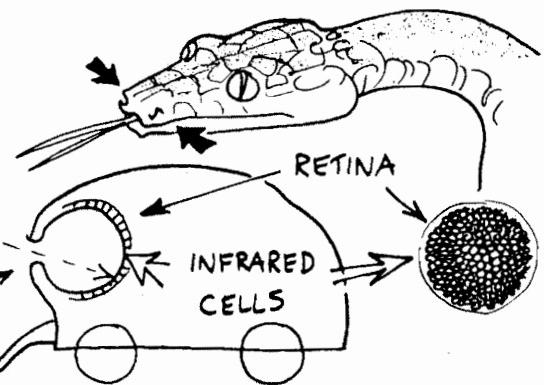
HE MEANS THAT IT REACTS  
TO ANY HEAT SOURCE.

YOU'VE GOT TO GIVE  
IT SOME SENSE ORGANS.

THERMAL  
RADIATION



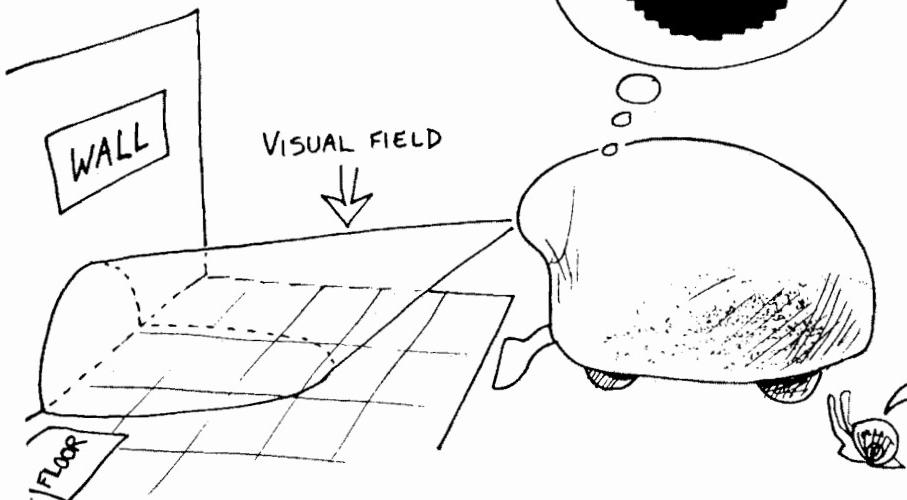
I'LL USE A FEW HUNDRED PHOTOCELLS TO BUILD A RUDIMENTARY "EYE," RATHER LIKE THE INFRARED-SENSITIVE "EYES" THAT SNAKES HAVE ON EITHER SIDE OF THE NOSE.



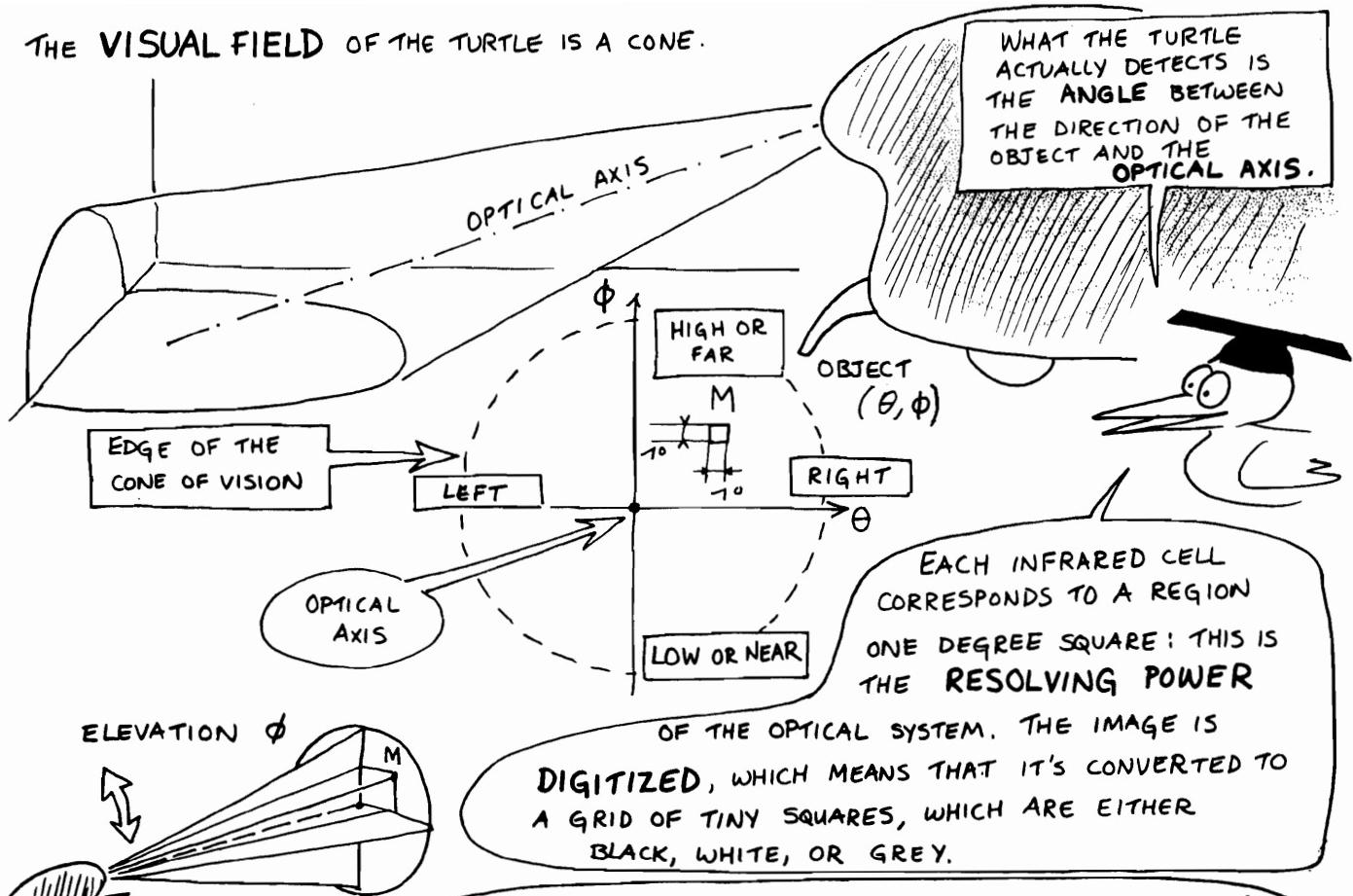
THE TILED FLOOR OF THE APARTMENT IS COLD. IF I ARRANGE FOR THE TURTLE TO TAKE THAT AS ITS ZERO-LEVEL FOR TEMPERATURE, IT WILL SEE THE FLOOR AS A BLACK BACKGROUND.



WALLPAPER'S A BIT WARMER, SO THE WALLS WILL APPEAR TO BE "GREY."



THE VISUAL FIELD OF THE TURTLE IS A CONE.



ELEVATION  $\phi$

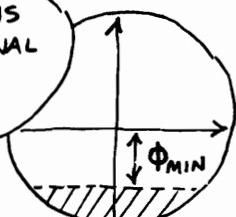
AZIMUTH  $\theta$

I'VE CHUCKED OUT THE OLD PROGRAM, AND NOW I'M GOING TO GIVE THE TURTLE A SIMPLE **REFLEX** WHICH WILL LET IT AVOID THINGS: "IF ONE PHOTOCELL DETECTS

A QUANTITY OF THERMAL RADIATION GREATER THAN SOME **THRESHOLD** VALUE, AND IF THIS SOURCE IS LOCATED BELOW A **HORIZON** (THAT IS, IF THE ELEVATION  $\phi$  OF THE OBJECT IS LESS THAN A VALUE  $\phi_{MIN}$ ), THEN THE TURTLE WILL MAKE A QUARTER-TURN TO THE RIGHT."

AMOUNT OF HEAT RADIATION GREATER THAN THE THRESHOLD; AND ANGLE  $\phi$  LESS THAN THE HORIZON VALUE  $\phi_{MIN}$ .

WHAT HE MEANS IS, IF THE SIGNAL IS IN THE SHADeD ZONE



IF SO, I TURN.

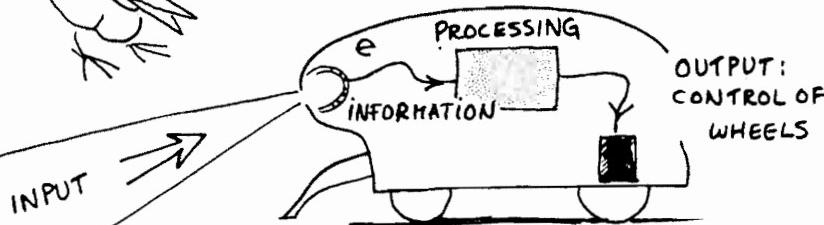
SO NOW THE TURTLE HAS  
BECOME AN INPUT-OUTPUT  
SYSTEM.



A BLACK BOX

WHAT'S INSIDE THE  
BLACK BOX?

A PROGRAM THAT LETS IT  
ANALYZE THE INPUT DATA (THE  
INFORMATION PROVIDED BY THE "RETINA") AND  
DECIDE WHAT RESPONSE TO MAKE:  
EITHER GO STRAIGHT AHEAD, OR MAKE A  
QUARTER-TURN RIGHT.



THIS TIME THE FAMOUS INVENTOR WILL REALLY CLEAN UP! HIS TURTLE  
WILL AVOID THE WALLS, AND ALSO THE FURNITURE, BECAUSE THEY'RE WARMER  
THAN THE TILED FLOOR.

GREAT! I'VE CRACKED IT! IT'S  
ALL PERFECTLY SIMPLE, AND NOW I  
CAN STOP WORRYING.

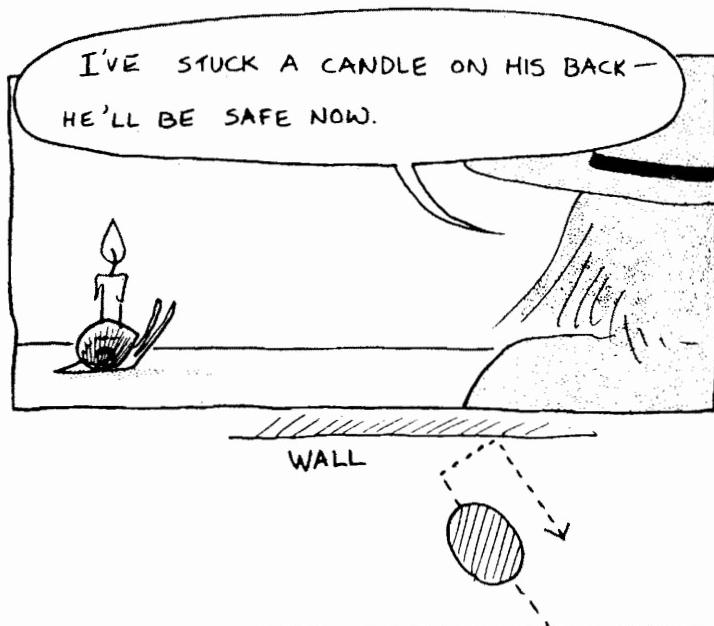
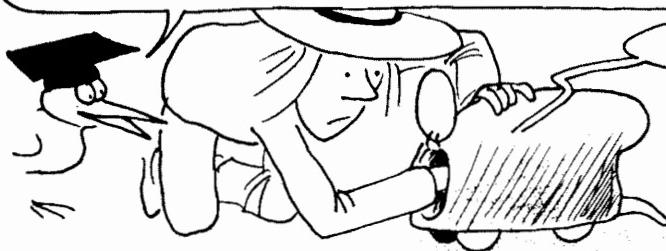
ARCHIBALD!

OH OH

THE TURTLE'S SWOLLED TIRESIAS!

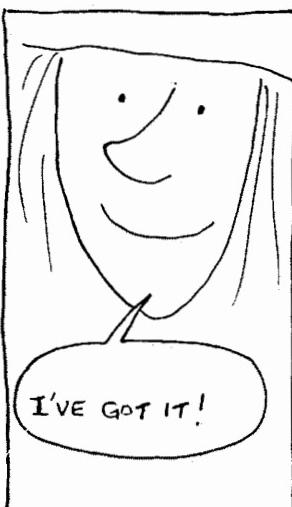
EH? HOW DID THAT HAPPEN?

TIRESIAS IS A COLD-BLOODED CREATURE, AND HIS FOOT MAKES GOOD THERMAL CONTACT WITH THE FLOOR. TO CUT A LONG STORY SHORT, HE HAS THE SAME TEMPERATURE AS THE FLOOR, SO AS FAR AS THE TURTLE IS CONCERNED... HE'S INVISIBLE!

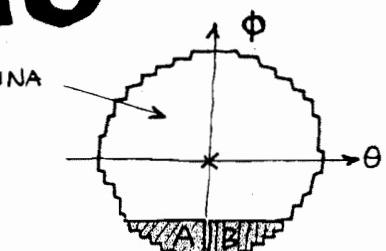
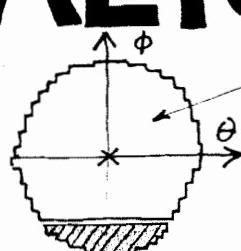


YES... IT'D BE MORE LOGICAL TO HAVE IT MAKE A LEFT TURN INSTEAD...

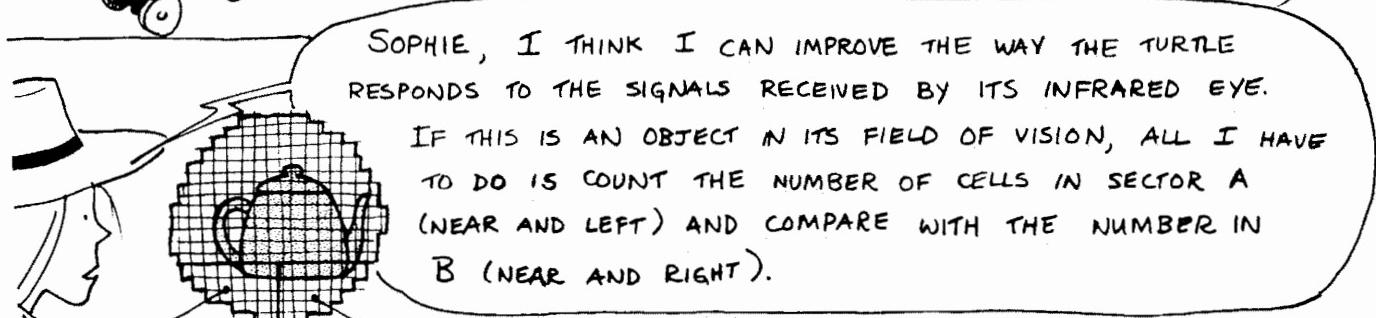
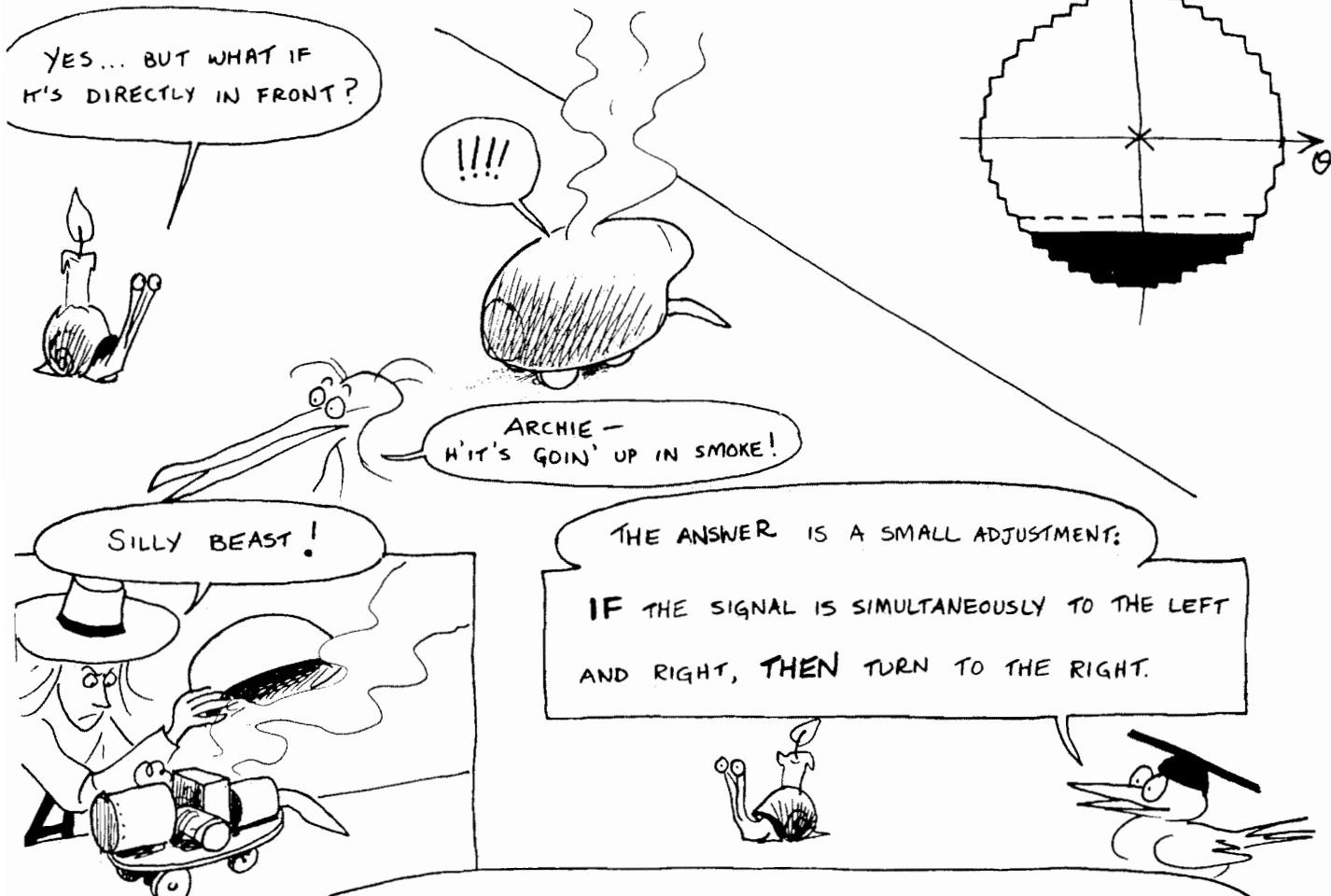
# SIGNAL ANALYSIS



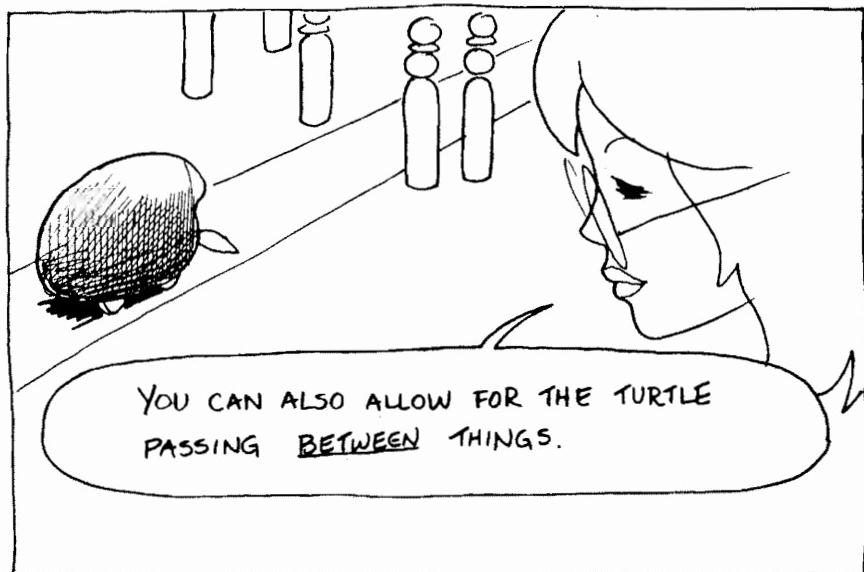
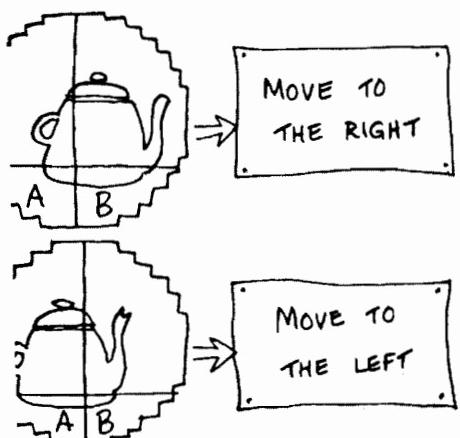
**OLD PROGRAM:**  
IF A WARM OBJECT APPEARS IN THE SHADeD ZONE, MAKE A QUARTER TURN TO THE RIGHT.

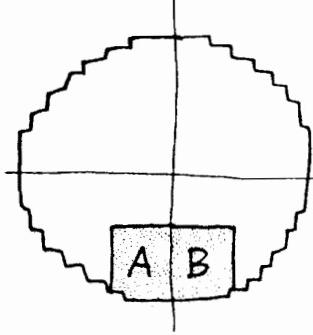


**NEW PROGRAM:**  
IF A WARM OBJECT APPEARS IN SECTOR A, MAKE A QUARTER TURN TO THE RIGHT. IF IN SECTOR B, MAKE A QUARTER TURN TO THE LEFT.



SECTOR A      SECTOR B





ALL I HAVE TO DO IS CUT SOME PIECES OFF THE TWO SECTORS A AND B ON THE RETINA.

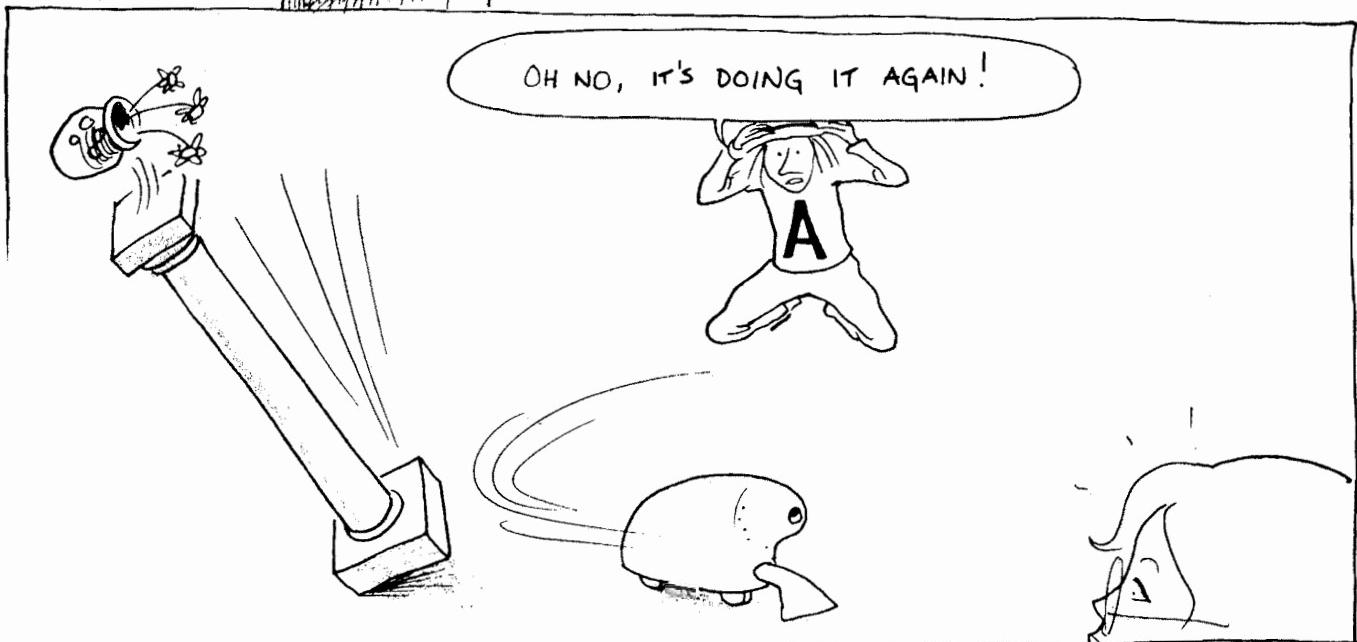


# RESPONSE TIME

THE MAIN POINT ABOUT MACHINES IS THAT THEY CAN GET THINGS DONE QUICKLY.



I'LL TURN IT UP TO THE HIGHEST SPEED.  
THAT WAY, THE CLEANING WILL BE DONE IN  
RECORD TIME.

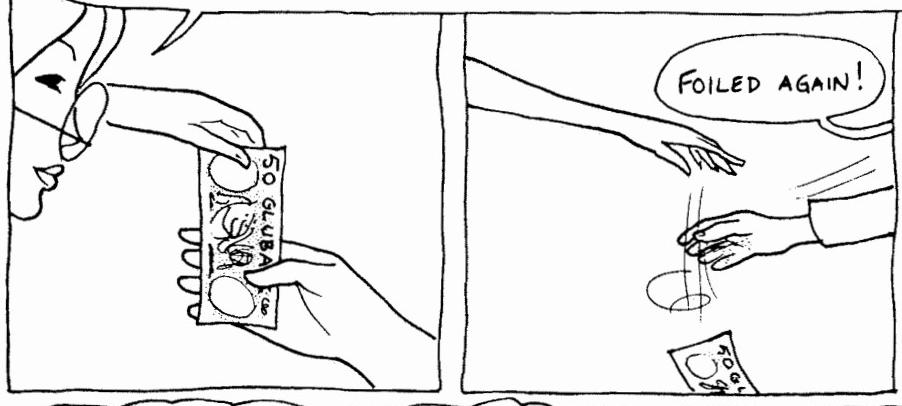


OH NO, IT'S DOING IT AGAIN!

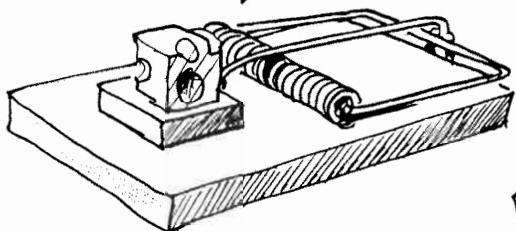
ARCHIE, IT'S NO GOOD EXPECTING A MACHINE TO REACT INSTANTANEOUSLY. BETWEEN THE INPUT AND THE OUTPUT YOU MUST ALLOW A RESPONSE TIME WHICH IS CHARACTERISTIC OF THE SYSTEM.



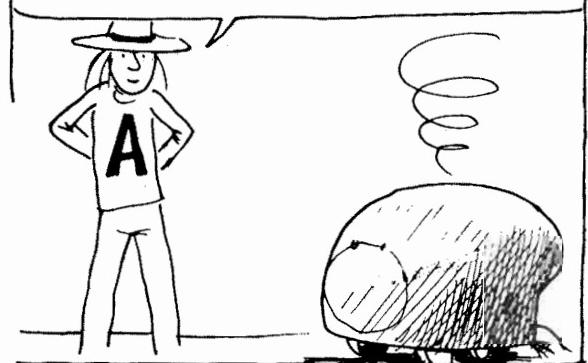
IT'S YOUR OWN RESPONSE TIME THAT PREVENTS YOU FROM CATCHING THIS BILL WHEN I LET IT DROP.



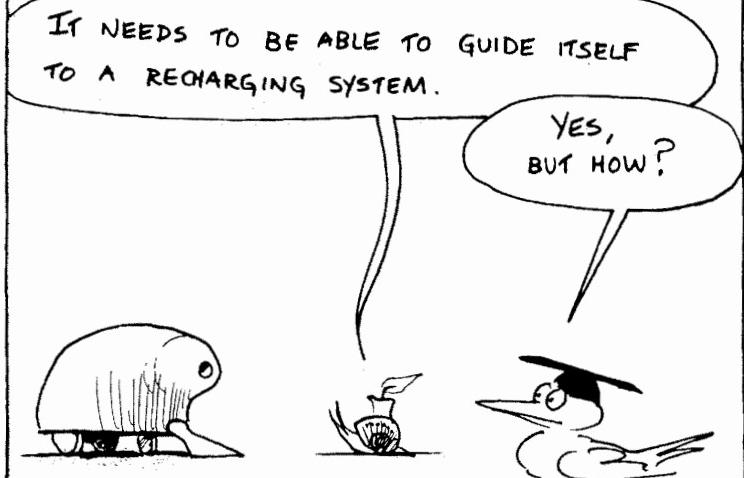
DANGER: INPUT-OUTPUT SYSTEM WITH SHORT RESPONSE TIME.



CLEANING THE APARTMENT GOBBLES UP LOTS OF ENERGY. THE TURTLE'S BATTERIES ARE FLAT.



IT NEEDS TO BE ABLE TO GUIDE ITSELF TO A RECHARGING SYSTEM.



# SERVOMECHANISMS

WHEN THE BATTERY STARTS TO GO FLAT, THE VOLTAGE ACROSS ITS TERMINALS DROPS. IT'S EASY TO ADD TO THE PROGRAM SOMETHING LIKE:

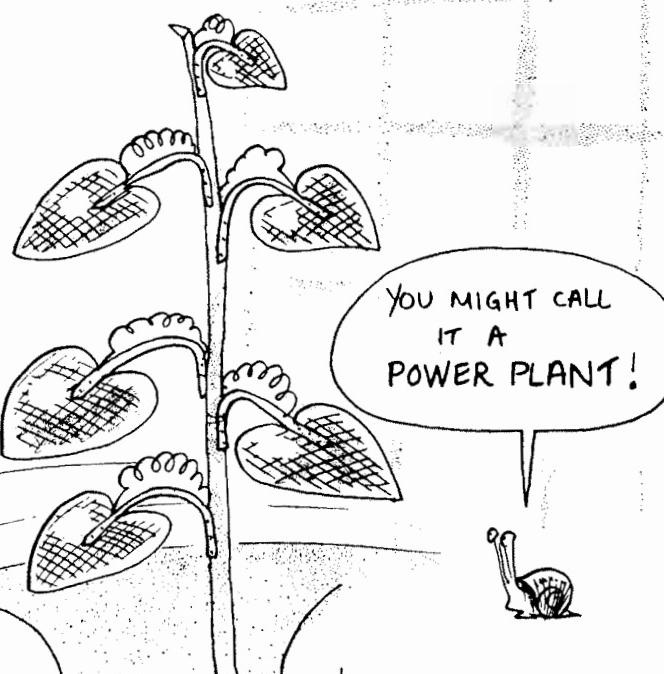
IF THE VOLTAGE BECOMES LOWER THAN... SO MANY VOLTS,

THEN GO AND GET CHARGED UP AGAIN.

BUT THE PROBLEM IS: HOW DO YOU GUIDE THE TURTLE TO THE RIGHT PLACE?



WHILE I'M WAITING FOR INSPIRATION, I'LL MAKE A UNIT THAT RECHARGES ITSELF USING SOLAR PANELS.



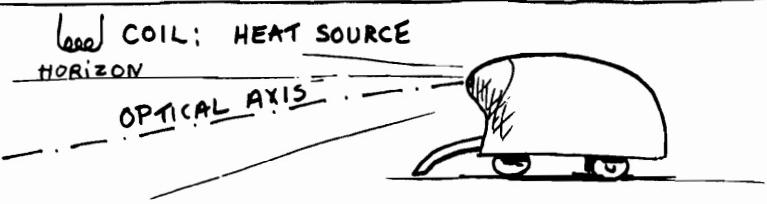
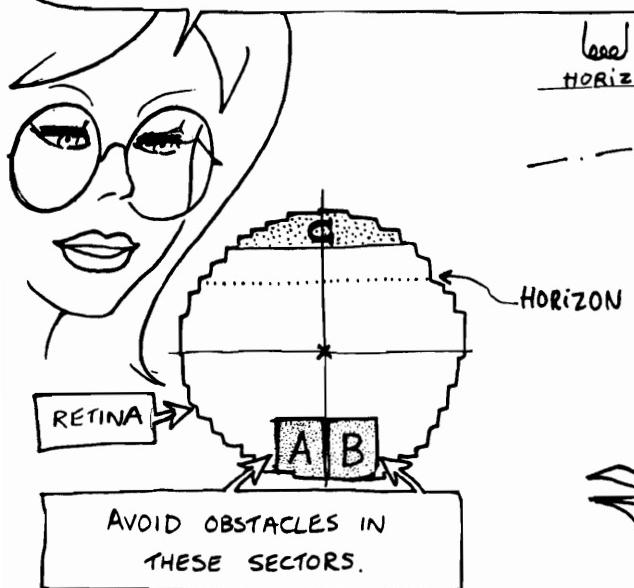
MAYBE I COULD GUIDE THE TURTLE BY USING THIS HEATING COIL... TROUBLE IS, IT TURNS AWAY FROM HEAT.



WHAT YOU NEED IS A LITTLE FEEDBACK.



THE TURTLE DOESN'T HAVE TO THINK OF THE COIL AS AN OBSTACLE, YOU KNOW.  
WHY DON'T YOU PLACE IT UP HIGH, TO ACT AS A BEACON?

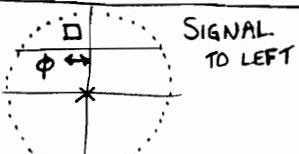
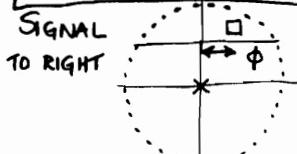


NOW IT'S EASY TO  
REPROGRAM THE TURTLE: IF THE CHARGE IN THE BATTERY FALLS BELOW SO  
MANY VOLTS THEN LOOK FOR THE COIL. THERE ARE TWO POSSIBILITIES.  
EITHER THE COIL IS ALREADY IN THE FIELD OF VISION, AND THE TURTLE  
CAN GO AFTER IT; OR IT'S NOT, IN WHICH CASE THE TURTLE STOPS, AND  
REVOLVES, UNTIL THE BEACON APPEARS.

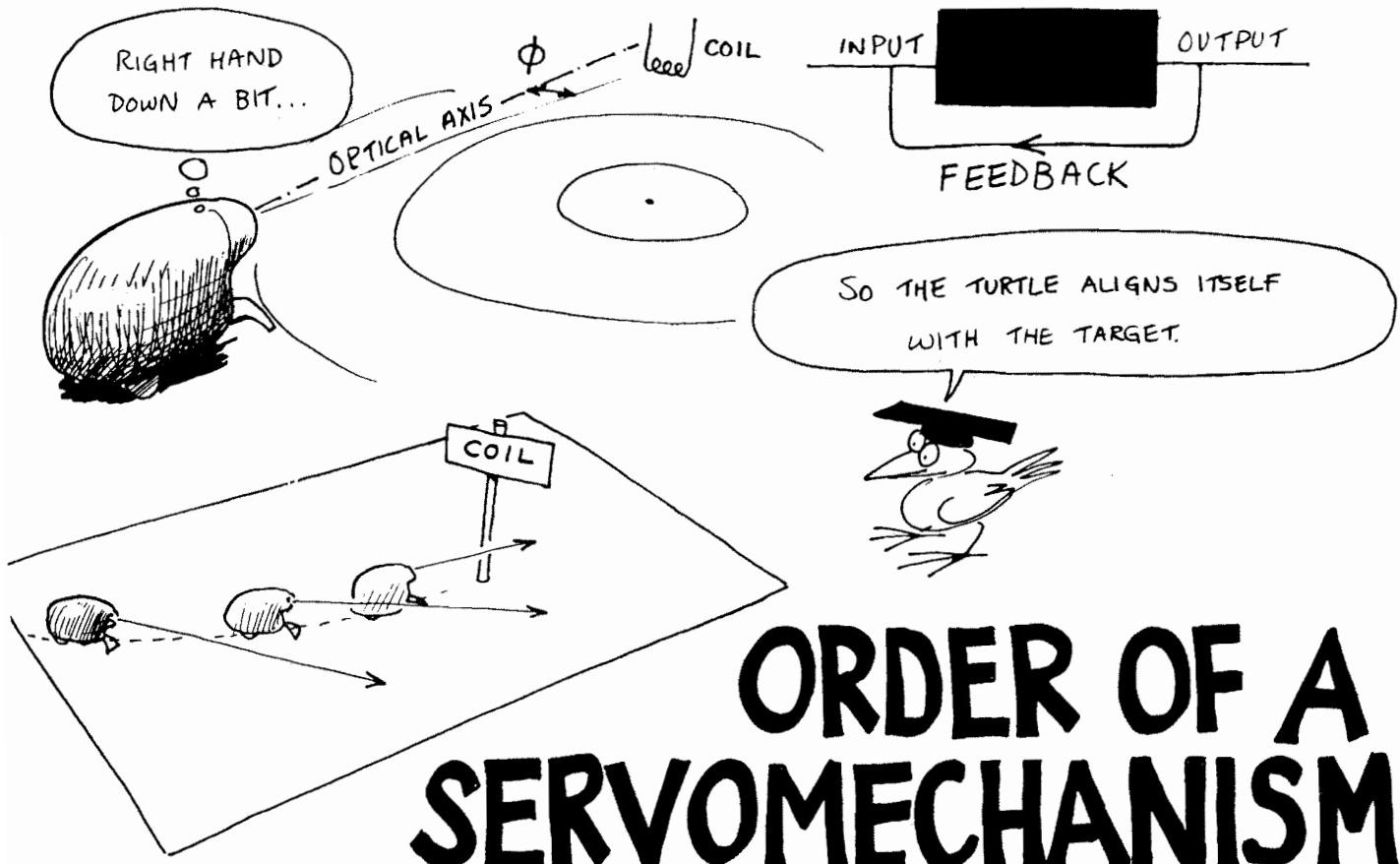


AS SOON AS THE TARGET COMES INTO VIEW, THE TURTLE  
CAN HOME IN ON IT BY FOLLOWING THIS PROGRAM:

TURN TOWARDS THE TARGET, BY AN AMOUNT  
PROPORTIONAL TO THE ANGULAR DEVIATION  $\phi$  BETWEEN  
THE TARGET AND THE CURRENT DIRECTION OF MOTION.  
THIS IS A LINEAR SERVOMECHANISM.



AS THE TURTLE STEERS TOWARDS THE TARGET, THE ERROR  $\phi$  CHANGES.  
SO  $\phi$  IS ACTING BOTH AS CAUSE AND AS EFFECT. THAT'S FEEDBACK!



## ORDER OF A SERVOMECHANISM

NOW, ARCHIE, LET'S PLAY A GAME. WHEN I GIVE THE SIGNAL, I WANT YOU TO PLACE THE POINT OF YOUR PENCIL NEXT TO MINE.



A CYBERNANTHROPOID.

I ADJUST THE MOTION OF MY PENCIL ACCORDING TO THE OBSERVED ERROR.

NOW, MORE QUICKLY!

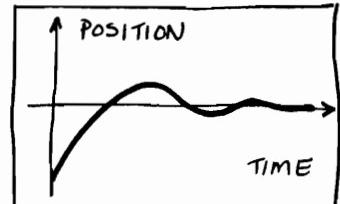
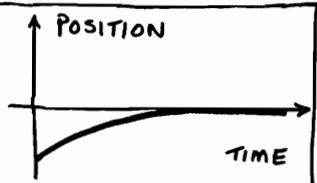
WHAT'S HAPPENING?

THE PENCIL GETS THERE IN THE END, BUT IT WOBBLES ALL OVER THE PLACE ON THE WAY!

THAT'S THE EFFECT OF INERTIA.

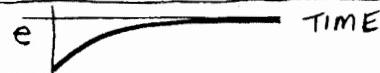
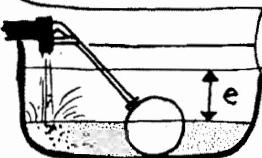
IN A FIRST ORDER SYSTEM, THE OUTPUT COMMANDS ACT DIRECTLY ON THE SPEED, WITHOUT ANY INERTIA. THERE ARE NO OSCILLATIONS.

IN A SECOND ORDER SYSTEM, THE OUTPUT COMMANDS ACT ON THE ACCELERATION BY WAY OF A FORCE. INERTIA LEADS TO OSCILLATIONS.

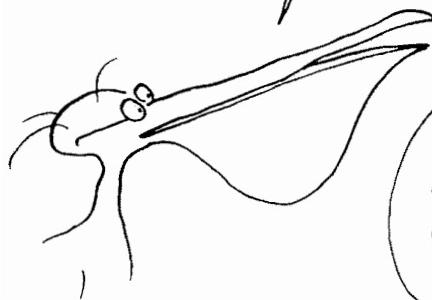


HUMANS ARE SECOND ORDER SYSTEMS. A GOOD EXAMPLE OF A FIRST ORDER SYSTEM IS A CISTERN.

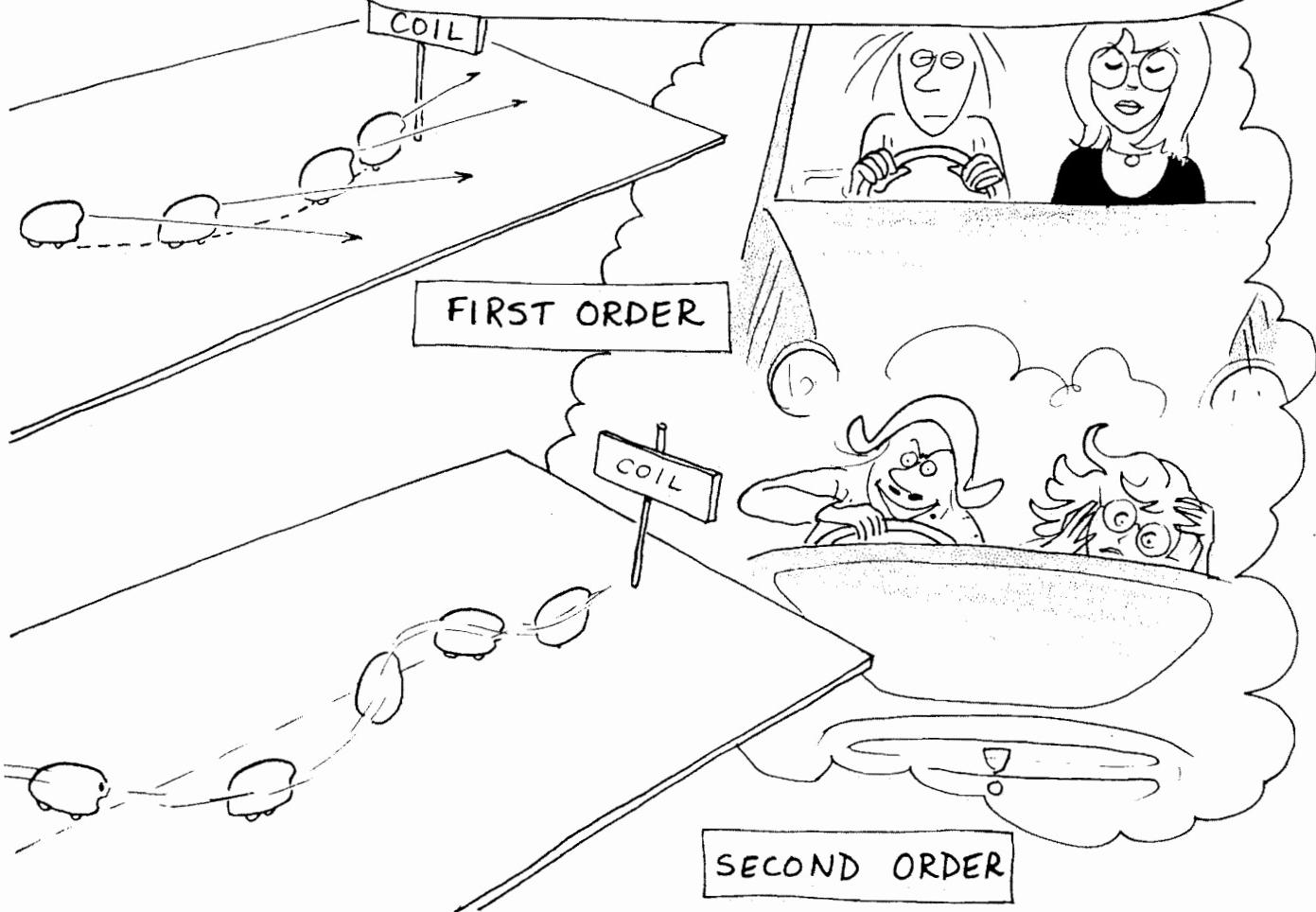
THE SPEED AT WHICH WATER RISES IS PROPORTIONAL TO THE DIFFERENCE FROM ITS FINAL POSITION.



WIV A FIRST H'ORDER CISTERN,  
THE WATER DON'T WOBBLE!



AT LEAST, THAT'S THE THEORY. BUT IN THE PHYSICAL NATURE OF THINGS, THERE'S ALWAYS SOME INERTIA PRESENT; AND IF YOU PUSH A BIT TOO HARD, IT SHOWS UP. SUCH A SYSTEM SEEMS TO BE FIRST ORDER BUT IS REALLY... SECOND ORDER.

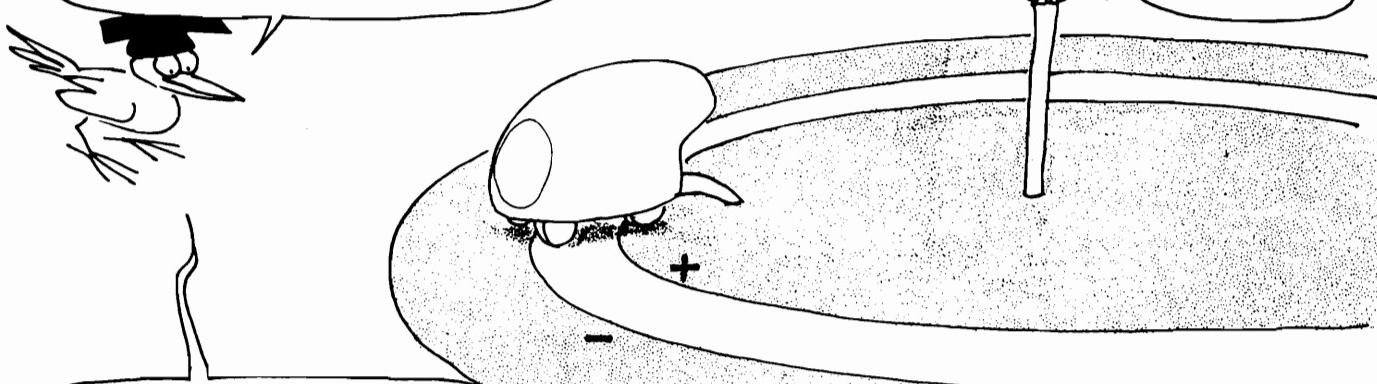


SOPHIE, LENNY THE PELICAN SAYS I'M SO SLOW THAT I'M INSENSITIVE TO INERTIA, AND I'LL NEVER BE MORE THAN A MERE FIRST ORDER SYSTEM.



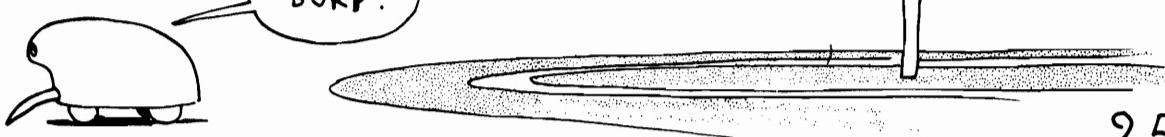
# CONTROL AND HOMEOSTATIC SYSTEMS

BUT NOW LET'S TALK TURTLE...



ARCHIE'S IDEA IS REALLY QUITE CLEVER. THE ELECTRIC TREE - THE "POWER PLANT" - GENERATES A FLOW OF CURRENT BETWEEN TWO CIRCULAR ELECTRODES. THESE ARE THE TURTLE'S WHEELS, COATED IN COPPER TO ENSURE GOOD CONTACT. ONCE THE BACK WHEEL MAKES CONTACT WITH THE ANODE AND THE FRONT WHEELS WITH THE CATHODE, THE TURTLE STOPS AND RECHARGES ITS BATTERY. WHEN IT'S FULLY CHARGED, THE TURTLE TURNS ROUND AND WANDERS OFF AGAIN, REFUELED. AS LONG AS THE CHARGE IN THE BATTERY IS REASONABLY LARGE, THE TURTLE IGNORES THE POWER PLANT, AND ITS GUIDING HOT WIRE, COMPLETELY.

BURP!



YOU DO JUST THE SAME - YOU STOP TO EAT WHEN THE PRESSURE ON THE WALL OF YOUR STOMACH DROPS BELOW A THRESHOLD VALUE.

ME... I?

STOMACHS WORK JUST LIKE CISTERNS.

YOU MEAN, CISTERNS WORK JUST LIKE STOMACHS.

THESE PHILLYSOFICKLE H'ARGUMENTS CAN GET QUITE DISGUSTIN' AT TIMES.

SYSTEMS LIKE THESE TRY TO MAINTAIN THEIR DEFINING PARAMETERS IN BETWEEN A MINIMAL AND MAXIMAL VALUE.

I SEE. SO WHEN I EAT OR DRINK, I'M ATTEMPTING TO MAINTAIN THE QUANTITIES OF SUGARS AND SALTS IN MY BODY, BETWEEN MINIMAL AND MAXIMAL VALUES.

ARE YOU TELLING ME THAT MAN  
IS JUST A MACHINE?

IF I WERE YOU, I'D SAY IT THE  
OTHER WAY ROUND. A MACHINE IS LIKE  
A MAN.

TECHNOLOGY WORKS BY PERFECTING  
OR EXTENDING WHAT GOES ON IN THE  
NATURAL WORLD.

ARTIFICIAL  
TOOTH

ARTIFICIAL HAIR

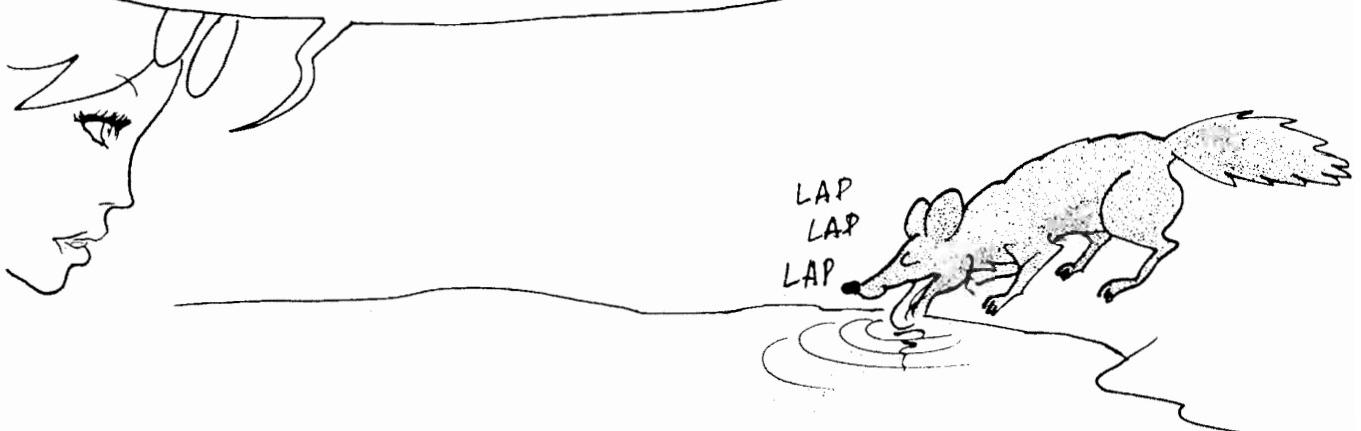
OWN ORIGINAL TEETH

NATURAL HAIR

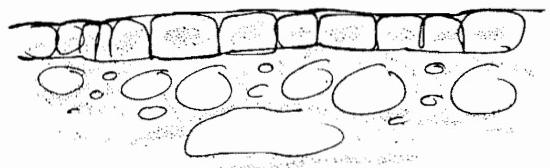
TO BEGIN WITH, WE COPIED THE FORMS  
OF LIVING THINGS. NOW WE'RE COPYING  
THEIR BEHAVIOR

RAPID-RESPONSE  
INPUT-OUTPUT SYSTEM

A LIVING CREATURE IS, AMONG OTHER THINGS, A FANTASTIC SELF-REGULATING HOMEOSTATIC MACHINE: MAINTAINING THE BALANCE OF ITS WATER, MINERALS, BLOOD COMPOSITION, TISSUES... EVEN ITS SHAPE.

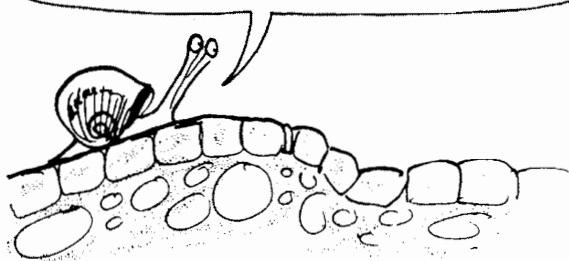


THE GROWTH OF SKIN CELLS IS INHIBITED BY CONTACT.



ANY DETECTABLE CHANGE IN ITS STATE FROM THE NORMAL VALUES DISTURBS THE NATURAL BALANCE.

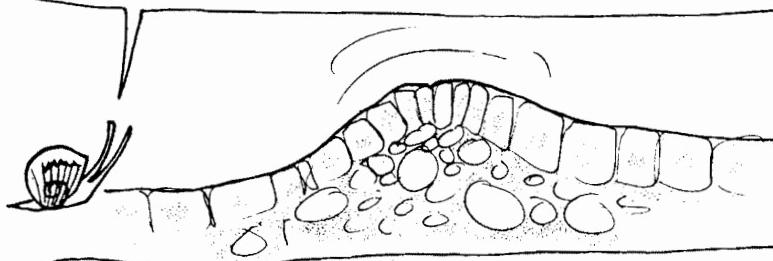
ANY DEFECT IN THE NATURAL BODY-ARMOR TRIGGERS OFF CELL-DIVISION AROUND THE EDGES OF THE CUT.



THE GROWTH IS INHIBITED ONCE CONTACT IS REESTABLISHED.



IF THE MECHANISM STOPS TOO SLOWLY, THE SCAR WILL BULGE.

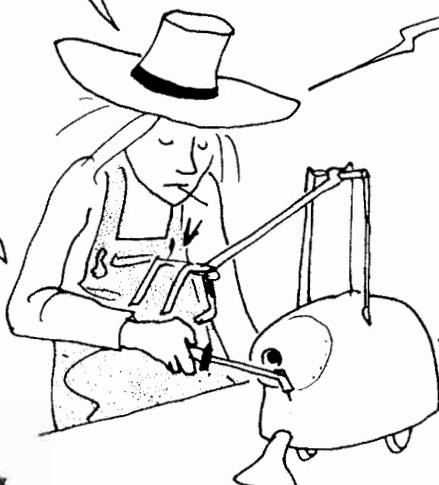
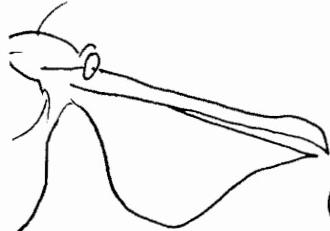


NAR WOT  
YER MAKIN'?

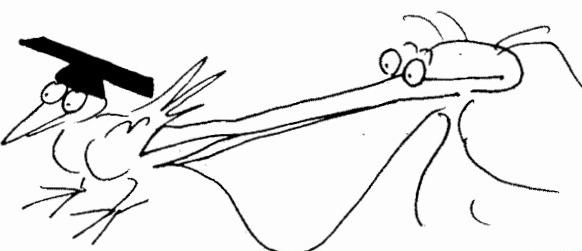
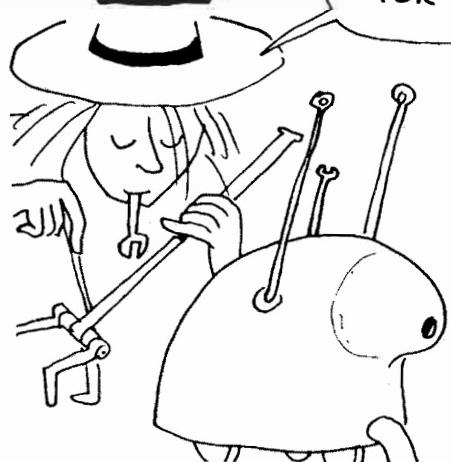
SOPHIE TOLD ME TO GET RID OF ALL  
THE MICE IN THE HOUSE. I'M GOING  
TO CATCH THEM.

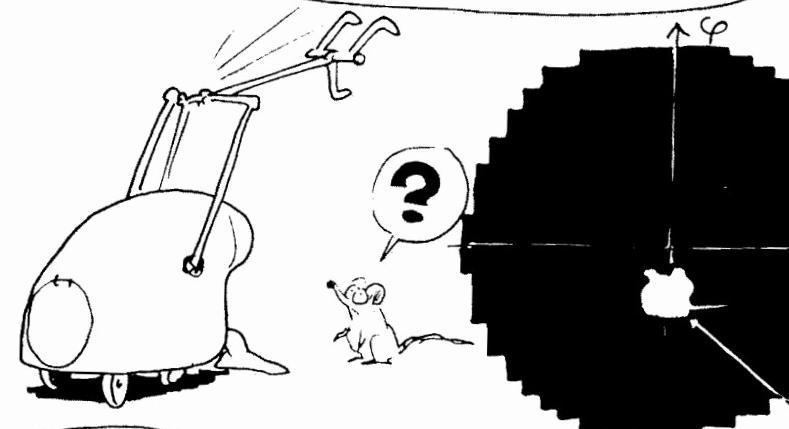
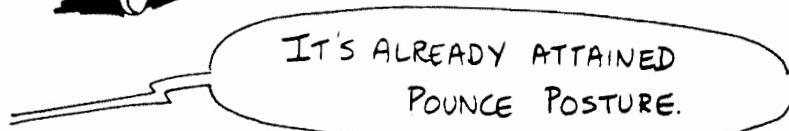
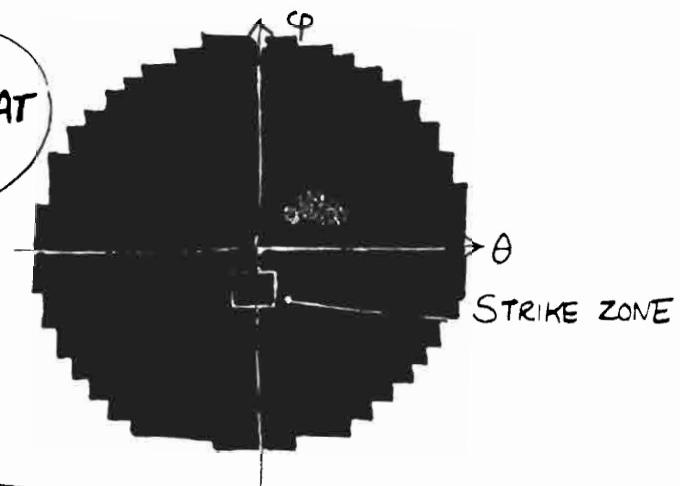
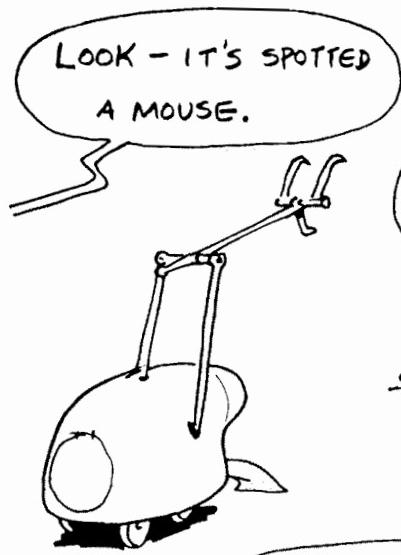
I'VE GIVEN MY TURTLE  
A PREDATION ARM AND A  
PURSUIT SYSTEM, ALL USING  
THE INFRARED EYE.

MICE ARE WARM-BLOODED: 107°



IT'S A MATTER OF THRESHOLDS AGAIN. THE FLOOR  
IS BLACK, THE WALLS AND THESE BOWLING PINS ARE  
GREY, AND THE MICE WHITE. ALL I HAVE TO DO IS  
PROGRAM THE TURTLE TO CHASE AFTER ANY BRIGHT  
OBJECT (EXCEPT IN SECTOR G, WHICH IS RESERVED  
FOR THE HOT WIRE BEACON ON THE POWER PLANT).





NOW IT MOVES  
FORWARD UNTIL THE  
MOUSE IS IN THE  
STRIKE ZONE.



ARCHIBALDDD!!

WILL YOU MAKE IT LET GO  
OF MY CUP - OR WHAT'S LEFT  
OF IT?

WOOPS

ME?

OH MY LORD - IT CAN'T TELL  
THE DIFFERENCE BETWEEN A MOUSE  
AND A CUP OF WARM COFFEE.

IT'S THE SAME  
PROBLEM THAT SNAKES  
HAVE WHEN THEY GO  
HUNTING AT NIGHT.

DO YOU  
HAVE  
SANKA?

NOT ONLY THAT - THE TURTLE WILL GET  
CONFUSED BETWEEN A NEARBY BOWLING PIN AND A  
DISTANT MOUSE (THE INTENSITY OF RADIATION VARIES  
AS THE INVERSE SQUARE OF THE DISTANCE).

TURTLE-LY SHORTSIGHTED.

AND I HOPE YOU REALIZE THAT WHEN  
WINTER COMES THE TURTLE WILL BE ALMOST  
BLIND.

WHY?

WE'RE HAVING A HEAT WAVE AT THE MOMENT!

I'M STUMPED.  
UTTERLY.

YOU COULD TRY MAKING  
IT HIBERNATE.

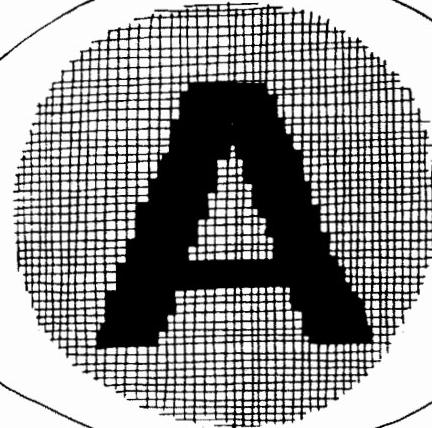
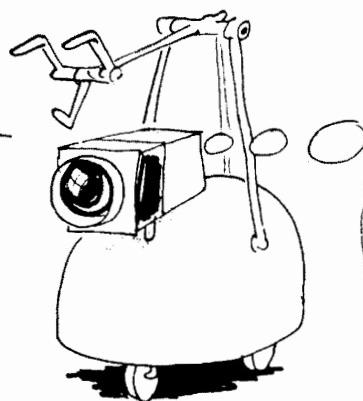
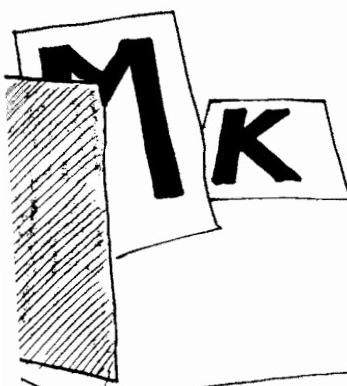
I'D SAY THE ANSWER IS TO MAKE  
THE TURTLE RECOGNIZE FORMS OF  
OBJECTS, SO THAT IT CAN IDENTIFY THEM.

CRIES, IF YER GOIN' TER TEACH IT TER  
RECKERNIZE SHAPES, WHY NOT TEACH IT TER  
BLINKIN' READ WHILE YER AT IT?

# PATTERN RECOGNITION



THIS HIGH-RESOLUTION TV CAMERA WILL BE AN IMPROVEMENT ON THAT INFRARED EYE.



EACH SHAPE THAT COMES INTO THE CAMERA'S VIEW CAN BE THOUGHT OF AS A SET OF POINTS, OR TINY CELLS WITH COORDINATES X AND Y HORIZONTALLY AND VERTICALLY.

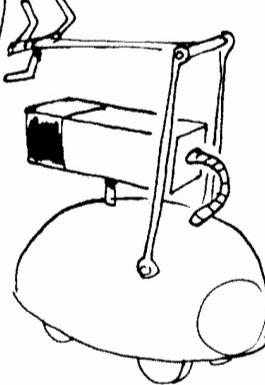
IN ORDER TO RECOGNIZE SOMETHING, YOU NEED TO HAVE SEEN IT BEFORE.

WE'LL HAVE TO START BY MAKING THE MACHINE MEMORIZE SOME BASIC FORMS.

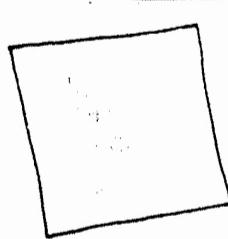


A B C D E F

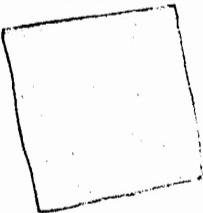
FOR INSTANCE, THE LETTERS OF THE ALPHABET



YUR - I SEES WOTCHA MEAN. THEN YER SHOWS THE MACHINE ANUVER LETTER, H'AN IT COMPARES IT WIV THE ONES H'IT ORLREDDY KNOWS.



SIGNAL

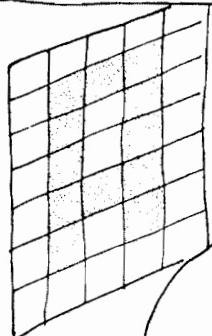
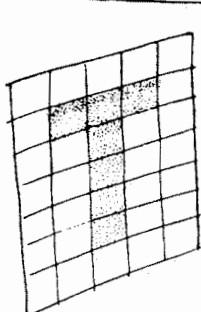


KNOWN SIGNAL

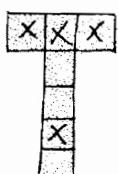
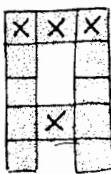
WHICH BOILS DOWN TO SUPERIMPOSING THE NEW SIGNAL ON THE NEGATIVE OF THE ORIGINAL ONE.



TO BE PRECISE, THINK OF THE SIGNAL AS A SET OF VALUES (0 OR 1)  
ASSIGNED TO THE COORDINATE CELLS (X, Y). THE ON-BOARD COMPUTER  
CAN COUNT THE TOTAL NUMBER OF COINCIDENCES OR NON-COINCIDENCES.



COINCIDENCES: 4 CASES.  
NUMBER OF CELLS IN SIGNAL: 7.  
FRACTION OF COINCIDENCES: 4/7.



YUR, BUT THERE'S A SNAG, MATE!  
YER TURTLE CAN ONLY RECKERNIZE A LETTER  
WOT'S H'EXACTLY LINED UP PROPER - AND  
THE RIGHT DISTANCE AWAY.



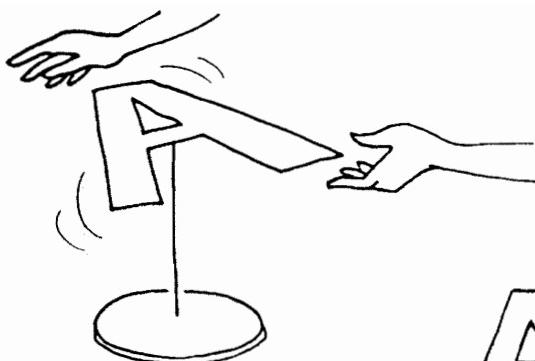
'AVE YER CALKYERLATED  
'OW LIKELY THAT IS?

OH HECK!  
THAT'S A TRICKY  
ONE...

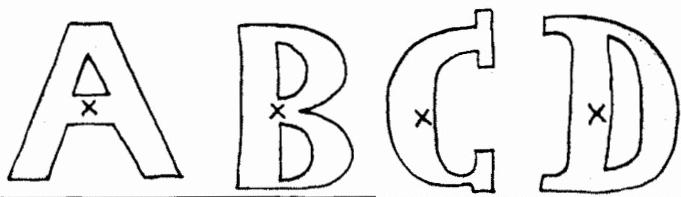


I THINK  
I'VE GOT THE  
ANSWER.

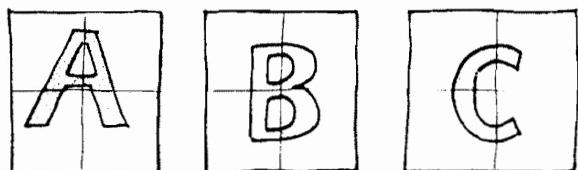




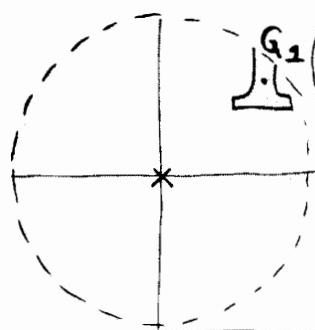
YOU WORK OUT THE CENTER OF GRAVITY OF EACH SYMBOL.



BEFORE RECORDING THE SYMBOL IN THE MACHINE'S MEMORY YOU ALIGN THE OPTICAL AXIS WITH THE CENTER OF GRAVITY.

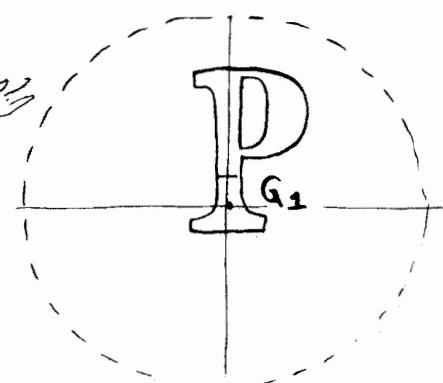
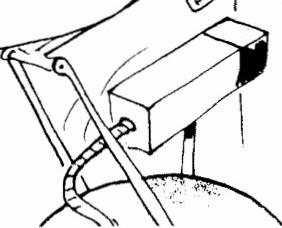


NOW, SUPPOSE SOME SHAPE ENTERS THE FIELD OF VISION.



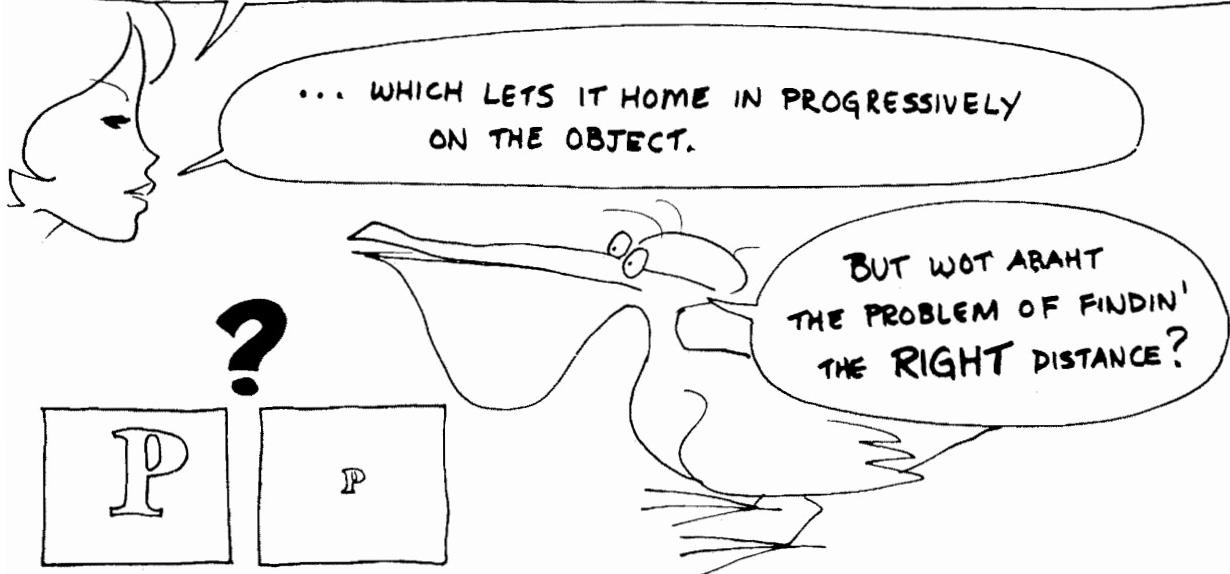
Straight away, we make the machine compute the center of gravity  $G_1$  of the part that it sees.

THEN IT MOVES THE CAMERA TO ALIGN THE OPTICAL AXIS WITH  $G_1$ .

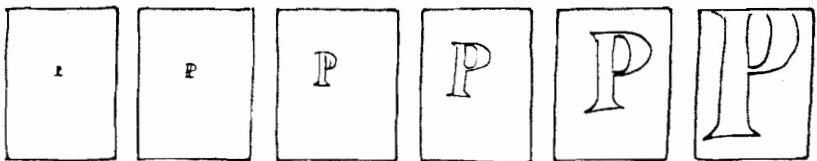


ONCE IT'S DONE THAT, THE MACHINE RECOMPUTES THE POSITION  $G_2$  OF THE CENTER OF GRAVITY OF THE NEW IMAGE, AND RECENTERS ITSELF ON THAT...

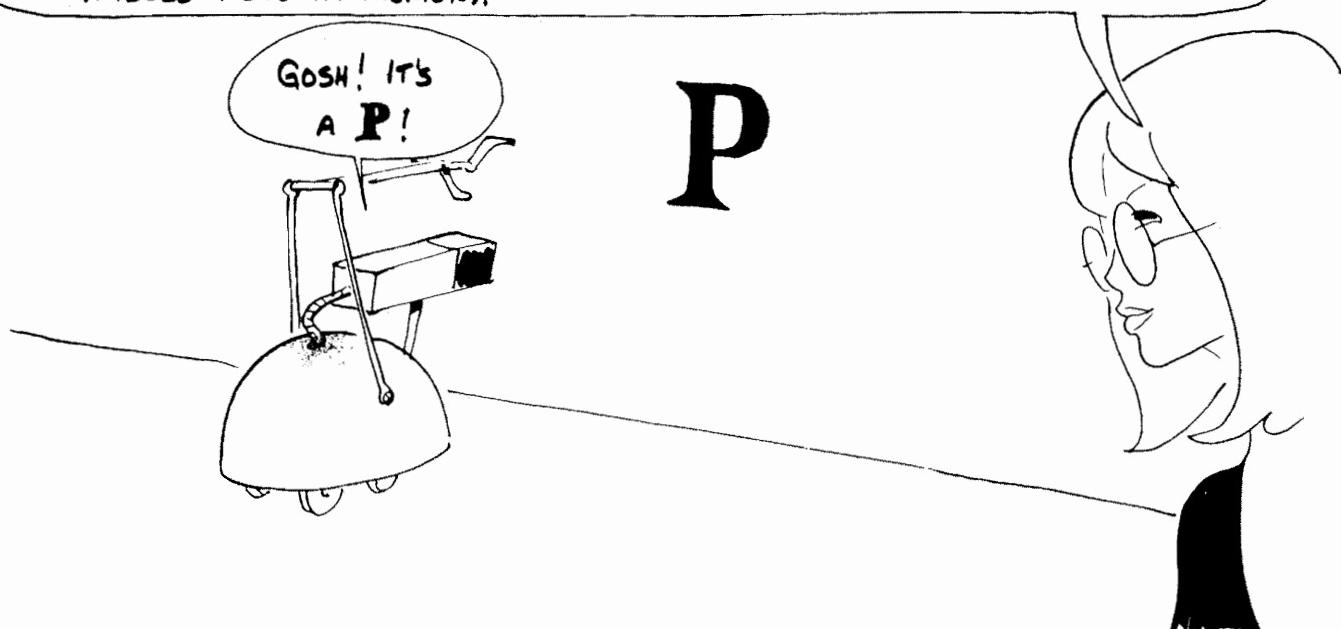
... WHICH LETS IT HOME IN PROGRESSIVELY ON THE OBJECT.



THE ON-BOARD COMPUTER CAN "DRAW N COPIES" OF THE IMAGE, ENLARGED OR REDUCED:



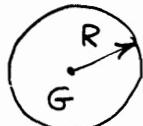
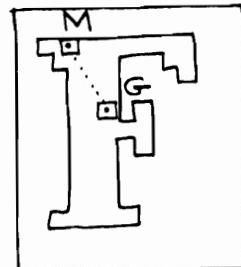
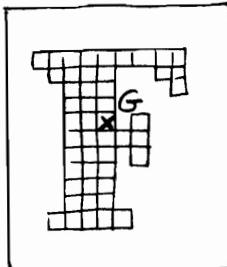
AND COMPARE EACH OF THESE WITH ITS REPERTOIRE OF STANDARD SYMBOLS HELD IN MEMORY.



HANG ON - YOU DON'T NEED TO GO THROUGH ALL THIS MAGNIFICATION LARK. SEEN FROM A DISTANCE, A SHAPE IS JUST A SORT OF BLOB. ITS IMAGE NOT ONLY HAS A CENTER OF GRAVITY - IT ALSO HAS AN APPARENT DIAMETER.



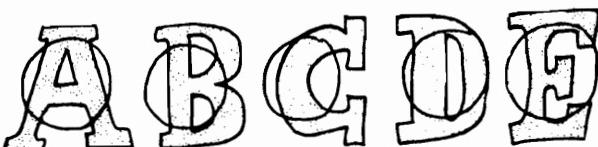
HOW ARE YOU GOING TO WORK OUT THE DIAMETER?



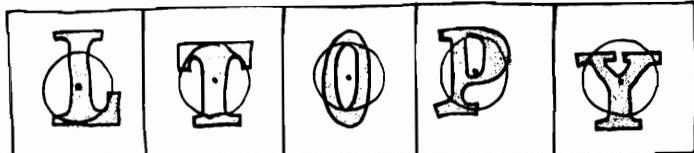
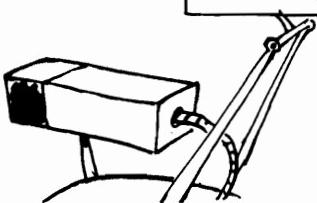
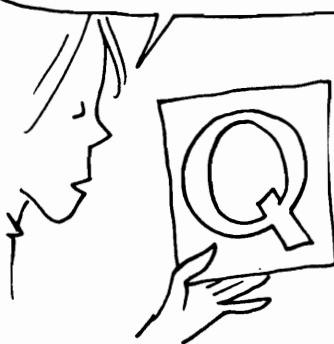
I LOOK AT ALL THE POINTS M THAT MAKE UP THE IMAGE, AND I JOIN EACH ONE TO THE CENTER OF GRAVITY G. I ADD UP ALL THE LENGTHS GM AND DIVIDE BY THE TOTAL NUMBER OF POINTS. I GET AN AVERAGE VALUE R, AND I SAY THAT  $D = 2R$  IS A MEASURE OF THE APPARENT DIAMETER OF THE IMAGE.



EACH LETTER OR SYMBOL HAS A CIRCLE ATTACHED TO IT, CENTERED ON G, AND OF DIAMETER D.

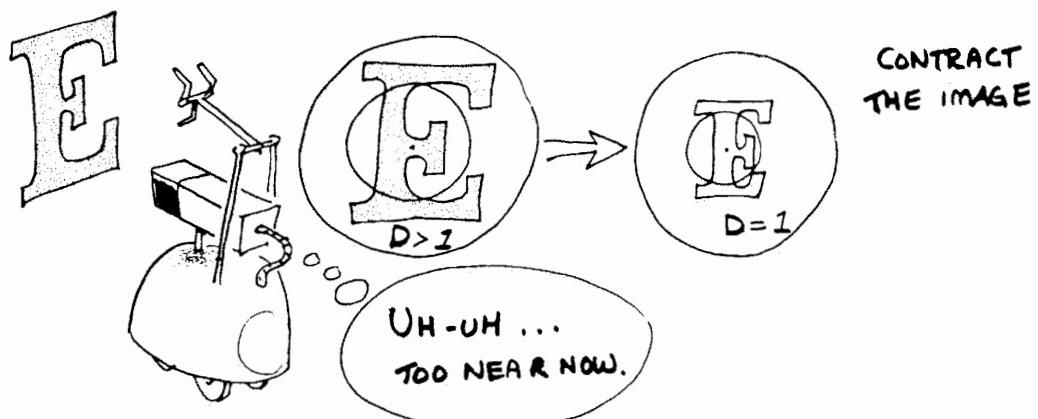
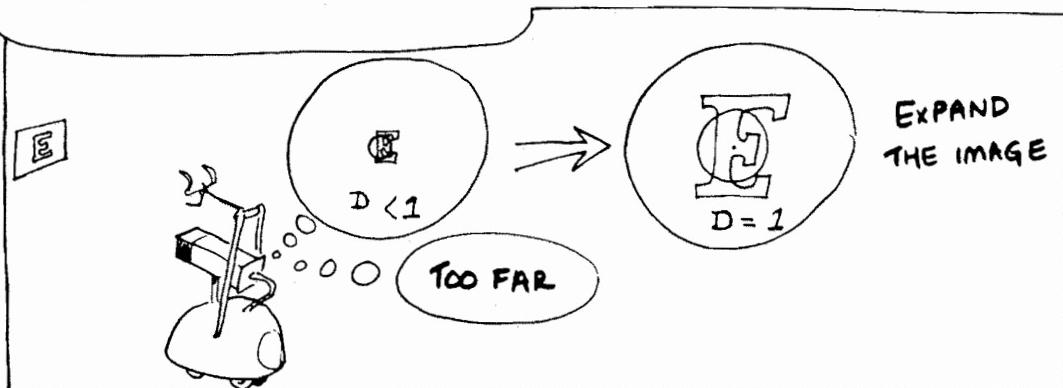


INSTEAD OF MEMORIZING THE SYMBOLS ANY OLD WAY, I ARRANGE FOR EACH TO HAVE THE SAME CENTER OF GRAVITY (SAY  $x_G = 0$ ,  $y_G = 0$ ) AND THE SAME APPARENT DIAMETER  $D = 1$ .

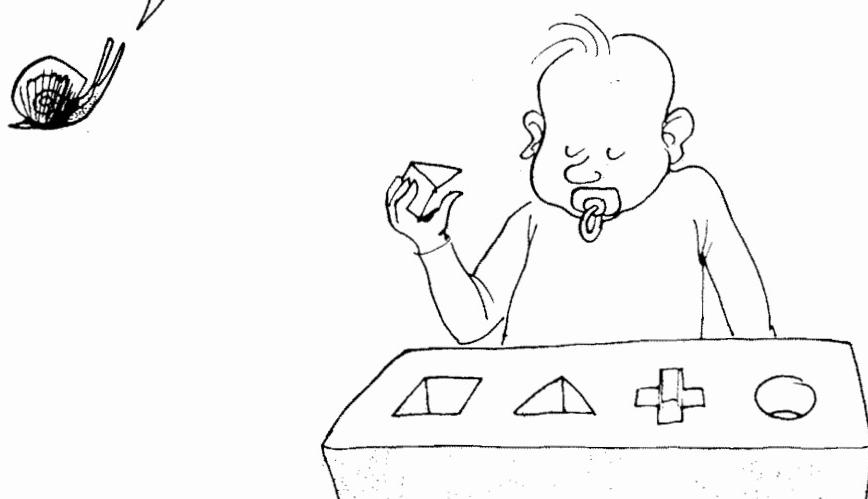


IN OTHER WORDS,  
YOU CENTER AND  
FOCUS THE SHAPE

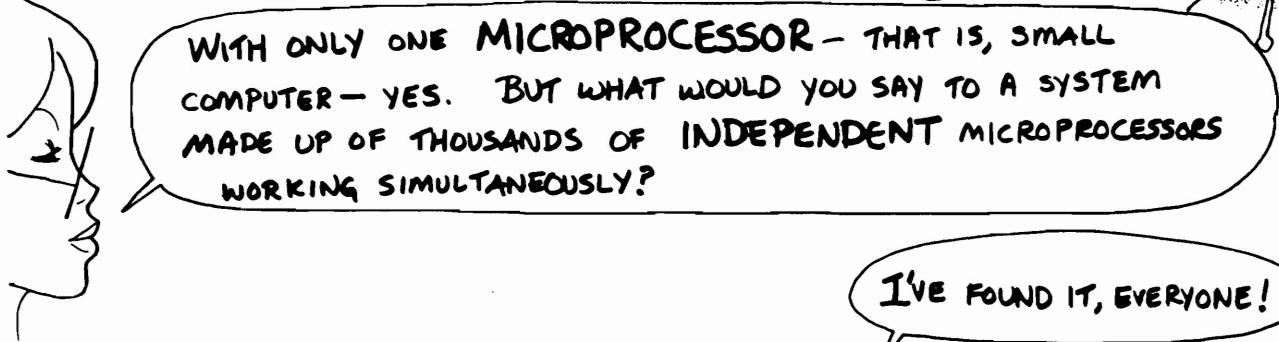
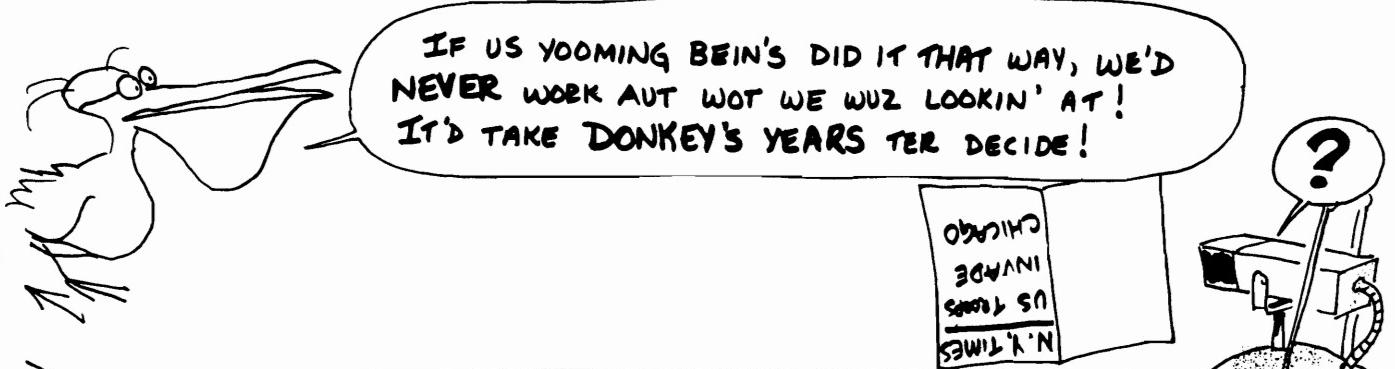
WE'VE ALREADY SEEN HOW THE TURTLE CAN AUTOMATICALLY ALIGN ITS OPTICAL AXIS WITH THE CENTER OF GRAVITY. IT CAN ALSO COMPUTE THE APPARENT DIAMETER  $D$  OF THE IMAGE. IF THIS IS NOT EQUAL TO 1, THE CAMERA CAN ZOOM IN OR OUT UNTIL IT IS.



ALL IT HAS TO DO NOW IS RUN THROUGH THE SHAPES IN ITS MEMORY, TO SEE WHICH ONE FITS BEST.



BUT IT'S ALSO POSSIBLE FOR THE LETTER TO BE ROTATED.  
THEN YOU HAVE TO MAKE COPIES OF  
EACH IMAGE YOU WANT TO TEST, ROTATED  
FROM  $0^\circ$  TO  $360^\circ$ .



A LIVING CREATURE— A HUMAN BEING, SAY— HAS SPENT A LOT OF TIME LEARNING HOW TO RECOGNIZE FORMS. AS YOU READ THESE WORDS, YOUR BRAIN, PROCESSING INFORMATION RECEIVED BY YOUR EYES, IS AS POWERFUL AS 10,000 MICROPROCESSORS WORKING SIMULTANEOUSLY IN PARALLEL.



BASICALLY, IT'S AMAZING THAT WE THINK OF OURSELVES AS A SINGLE CREATURE AT ALL.

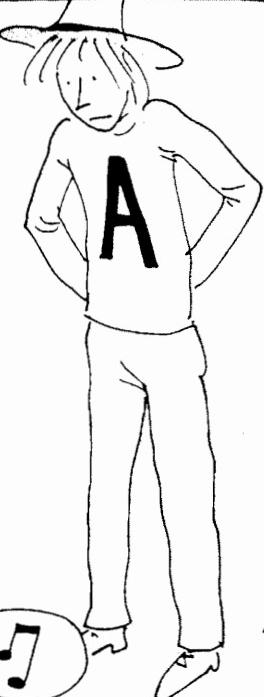
WHICH BOGGLES MY MIND



ACTUALLY, PATTERN RECOGNITION IS AN EXTREMELY COMPLICATED PROBLEM. WHAT WE'VE SHOWN YOU IS JUST A ROUGH OUTLINE.

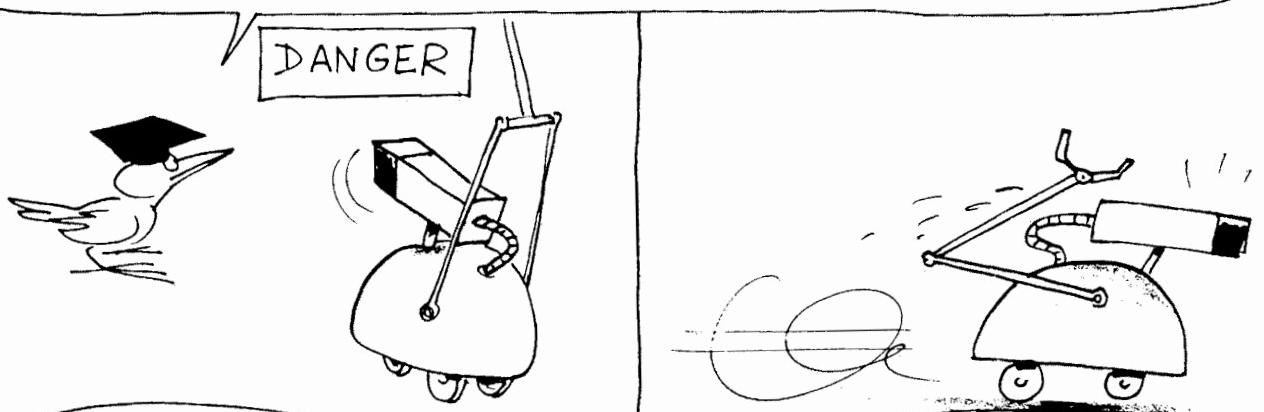


A TURTLE NOT CAN READ.



NOW I'VE SEEN IT ORL.

IF THE TURTLE CAN READ LETTERS, IT CAN ALSO PUT THEM TOGETHER TO RECOGNIZE WORDS, OR SENTENCES.

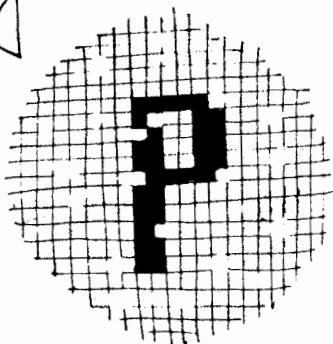


NOW THIS IS AN  
INTERESTING  
EXPERIMENT.



GOSH, IT'S SNOWING!

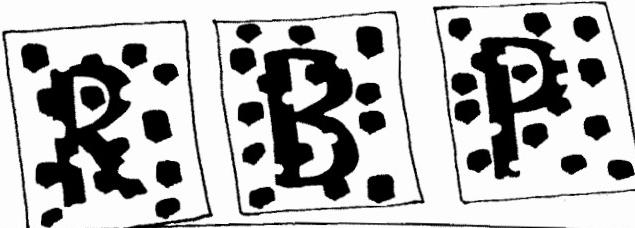
HERE'S THE LETTER THE WAY THE TURTLE SEES IT AT A GIVEN MOMENT.



# NOISE

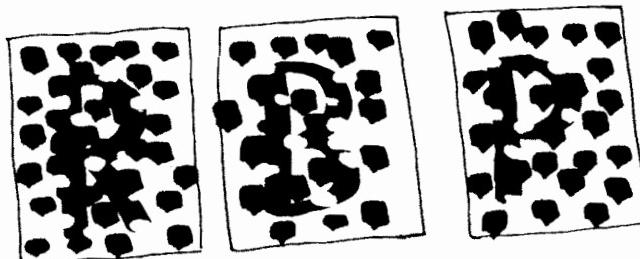
EACH IMAGE IS DISTORTED BY BACKGROUND NOISE.

HERE'S ONE IDEA: 100% AGREEMENT ISN'T REALLY NECESSARY TO BE ABLE TO RECOGNIZE A SIGNAL.



NOISE NOTWITHSTANDING, THESE SIGNALS ARE PERFECTLY CLEAR, AND DISTINGUISHABLE.

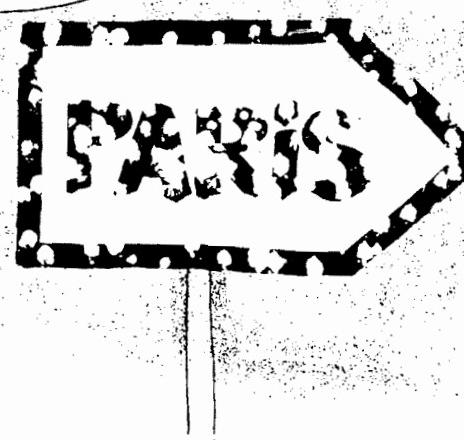
THE AGREEMENT IS NO MORE THAN 75%



I CAN'T RECOGNIZE A THING NOW!

BUT... SUPPOSE YOU TAKE SEVERAL IMAGES OF THE SAME NOISY OBJECT.

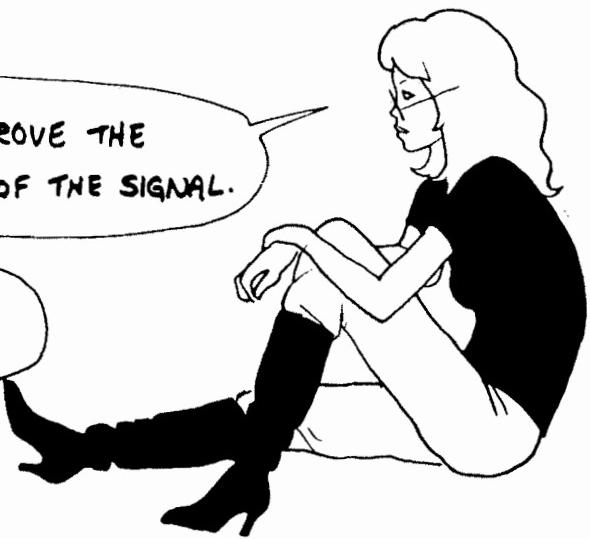
I MIGHT POINT OUT THAT SINCE WE HAVE TWO EYES, WE ALWAYS WORK WITH TWO IMAGES ANYWAY



# IMAGE PROCESSING

By combining  $N$  images, you can improve the level of perception, the detection of the signal.

For instance, you can superimpose them (or take an average).



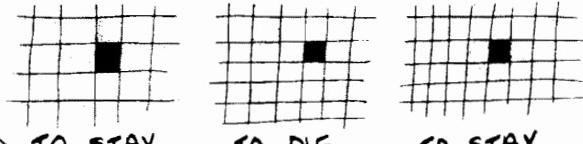
There are also more sophisticated mathematical techniques.

When I hide the signal with my hand, I can't read it.



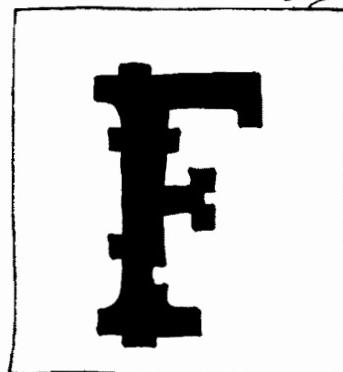
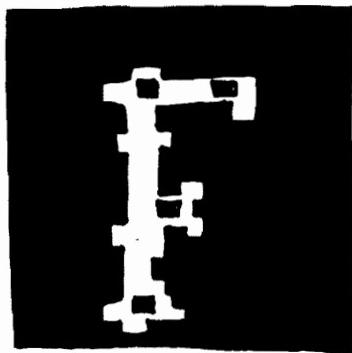
LESSEE IF I GOT YER DRIFT RIGHT. YER WANNA BE ABLE TER RECKERNIZE SIGNALS NO MATTER WOT'S 'APPENIN' - SNOW, 'AIL, 'URRICANES AN' WOTNOT. NAR THAT MEANS YER NEED TER COMPUTE ORL THIS MONKEY-BUSINESS WIV CENTERS O' DEPRAVITY AN' H'APPARENT DYNAMOMETERS 'OW D'YER PLAN TO DO THAT WIV ORL THIS BACKGROUND NOISE?

I THINK I'VE GOT AN IDEA. WE "CLEAN UP" THE IMAGE. SUPPOSE WE LOOK AT EACH POINT IN TURN AND ELIMINATE ALL THOSE THAT HAVE FEWER THAN TWO NEIGHBORS?



THAT WILL GET RID OF MOST OF THE ISOLATED BLOTCHES.

THEN YOU "INVERT" THE IMAGE AND DO IT AGAIN.



HERE'S WHAT YOU GET AFTER THE SECOND CLEANING OPERATION.

HOKAY, YER TURTLE CAN  
READ IN THE SNOW.  
SO WOT?

LENNY: PRETEND  
THAT THE TURTLE'S EYE  
IS AS GOOD AS A HUMAN'S.

THE NUMBER OF  
PICTURE CELLS THAT CAN BE  
DISTINGUISHED IS GREATEST  
NEAR THE MIDDLE.

To read a message,

AROUND THE SYMBOLS ERRATICALLY.

THE EYE'S OPTICAL AXIS JUMPS

'jr nond r mning'

To read a message

ONLY A FEW REGIONS ARE PERCEIVED  
WITH ANY CLARITY.

BUT THE BRAIN RECONSTRUCTS THE MOST LIKELY MESSAGE.

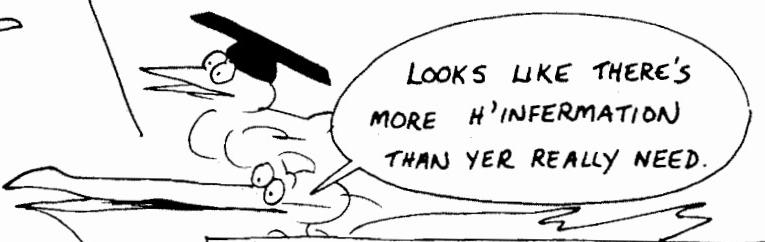
WHICH LETS US READ  
VERY RAPIDLY.



IT'S REASONABLE ENOUGH. TO GATHER **ALL** THE INFORMATION, READ THE MESSAGE WORD BY WORD, THE WORDS LETTER BY LETTER, THE LETTERS STROKE BY STROKE - YOU'D NEVER GET STARTED!



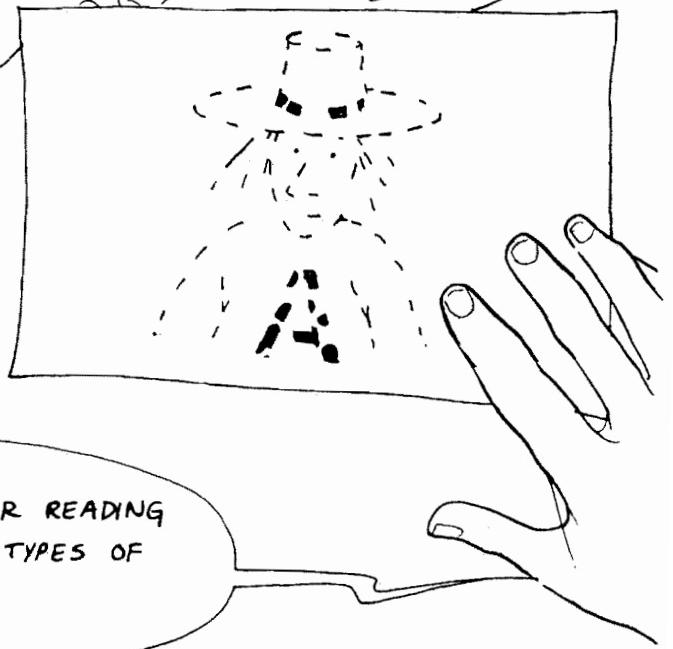
CERTAIN KEY FORMS LET US IDENTIFY LETTERS.



TWO GLANCES AT THE START AND FINISH OF A WORD ARE USUALLY ENOUGH.



AND WHAT GOES FOR READING IS ALSO TRUE OF OTHER TYPES OF PERCEPTION.



IF YOU GET THE IMPRESSION SOMETHING'S NOT QUITE RIGHT, THE EYE TAKES ANOTHER QUICK GLANCE AT THE PROBLEM AREA.

# PERCEPTION

WE THINK WE'RE RECEIVING INFORMATION ALL THE TIME.



BUT ALL WE ACTUALLY TAKE FROM OUR SURROUNDINGS IS THE **MINIMUM** OF INFORMATION NEEDED TO IDENTIFY SHAPES, SOUNDS, AND SO FORTH.

ALL THE TIME, THESE IMPRESSIONS ARE COMPARED TO AN ENORMOUS BANK OF SIGNALS AND SYMBOLS IN OUR MEMORIES...



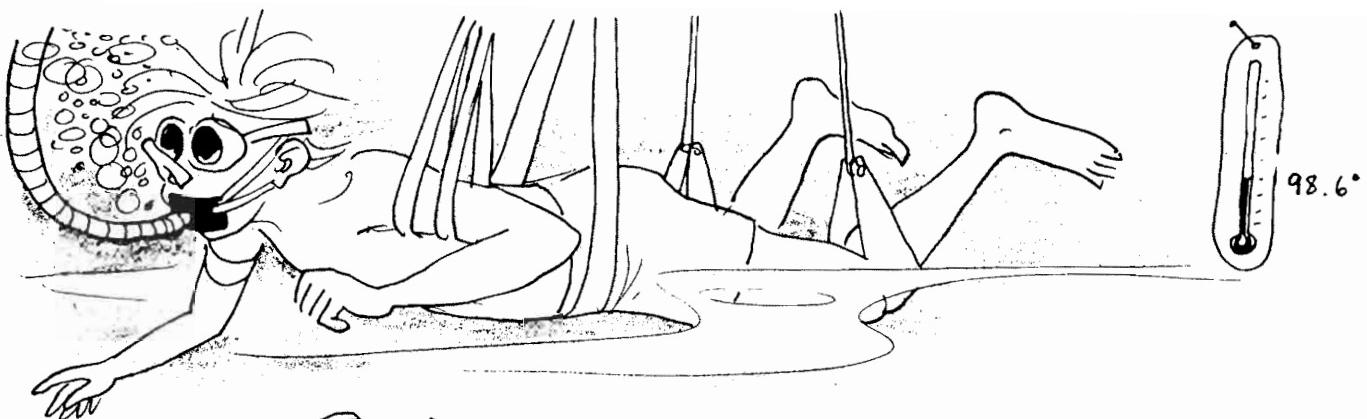
A memory written in the sand

... WHICH ARE CONSTANTLY REFRESHED

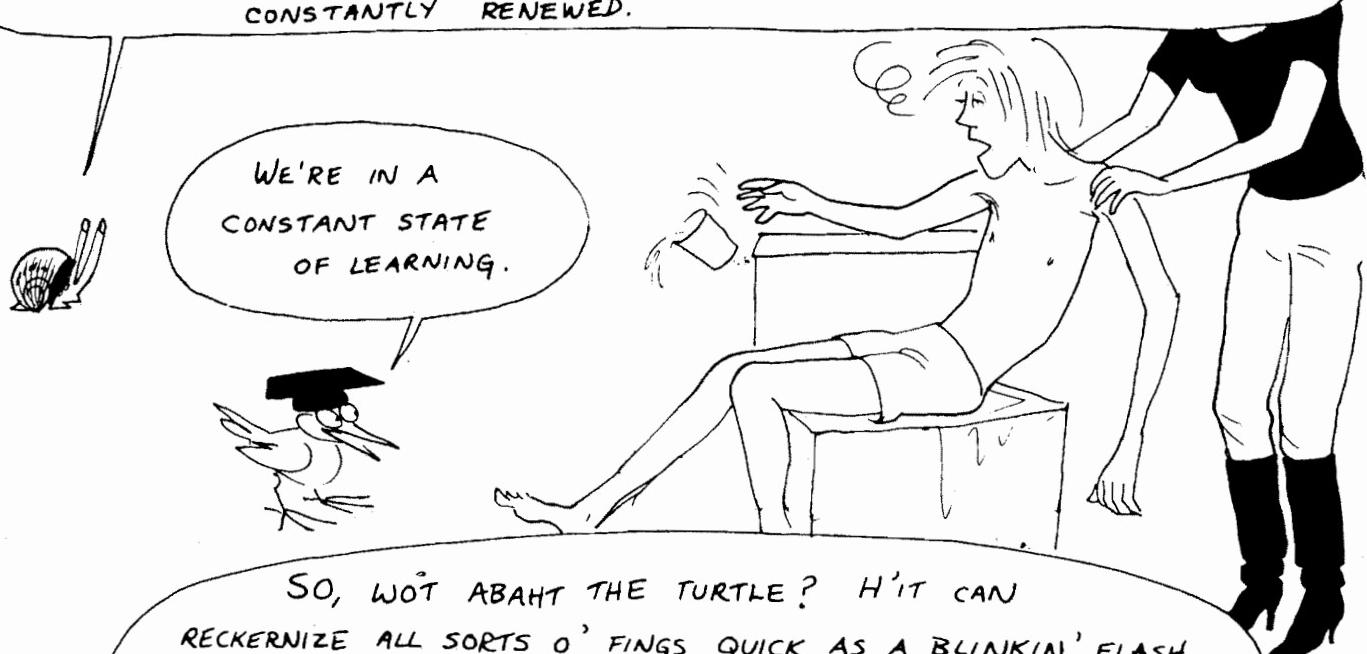


IT'S BEEN DISCOVERED THAT IF YOU CUT SOMEONE OFF FROM ALL OUTSIDE SENSATIONS, THE MIND QUICKLY STARTS TO DRIFT...

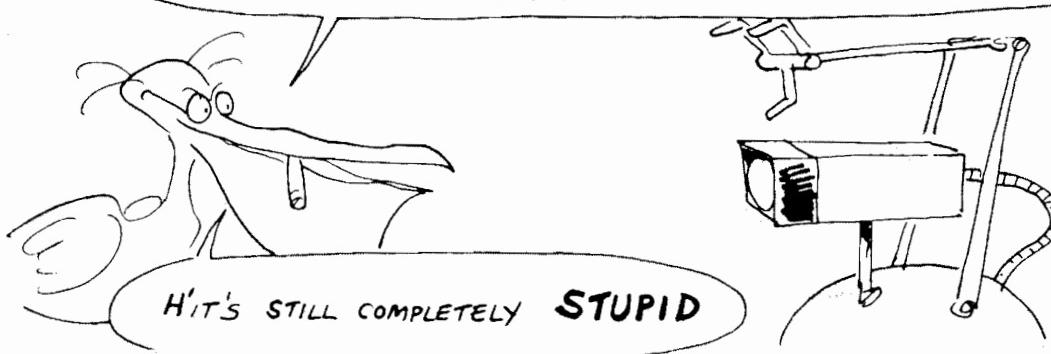




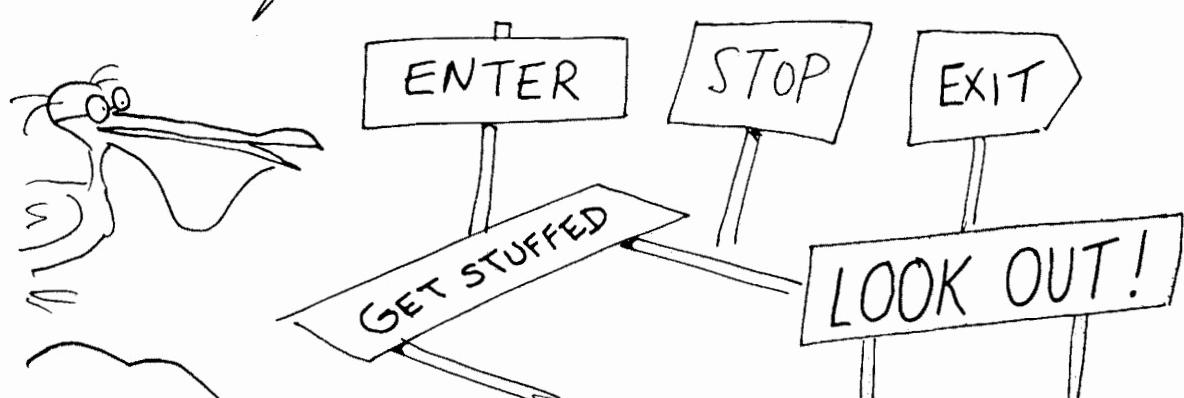
AFTER A FEW DAYS OF SUCH **SENSORY DEPRIVATION** ONE CAN HARDLY  
MANAGE EVEN VERY SIMPLE ACTIONS, LIKE PICKING UP A GLASS. IT'S AS  
IF THE IDEA THAT WE ARE PART OF THE OUTSIDE WORLD NEEDS TO BE  
CONSTANTLY RENEWED.



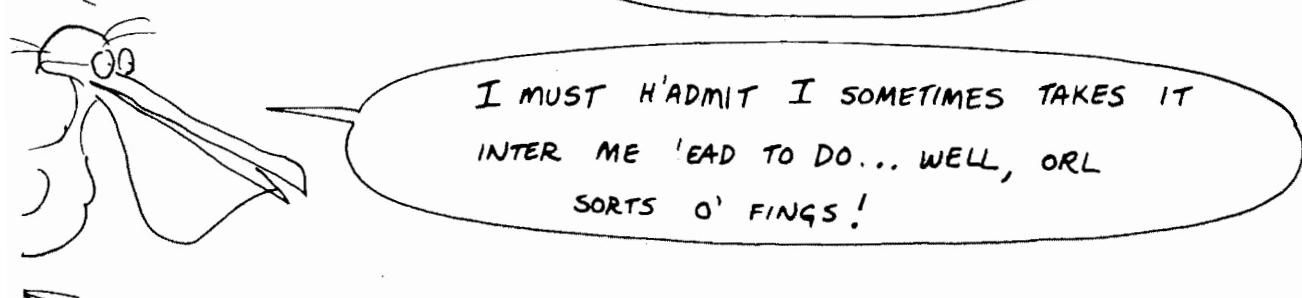
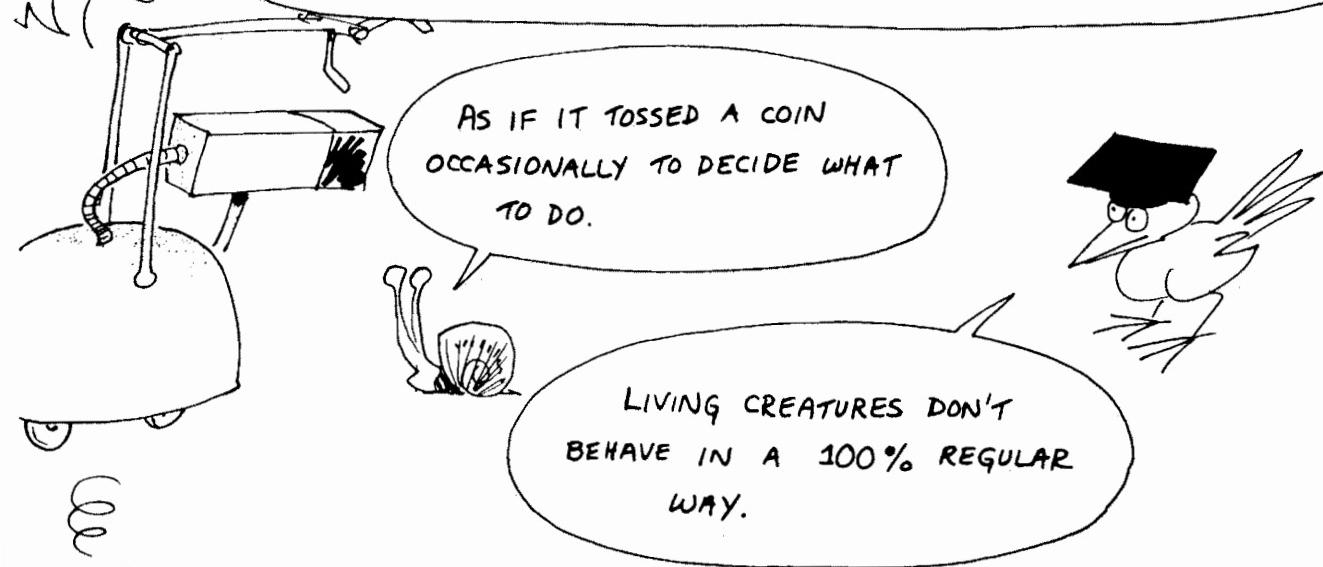
SO, WOT ABAHT THE TURTLE? H'IT CAN  
RECKERNIZE ALL SORTS O' FINGS QUICK AS A BLINKIN' FLASH,  
COME RAIN, SLEET OR SNOW; H'UPSIDE DAHN OR  
H'INSIDE AUT. **SO WOT?**



THE ONLY FINGS IT CAN DO ARE WOT YOU PUT INTO ITS SILLY 'EAD



YOU COULD TRY ADDING A RANDOMIZING DEVICE TO GIVE THE TURTLE'S BEHAVIOR A BIT OF VARIETY.



# INTELLIGENCE AND STUPIDITY



INTELLIGENCE IS SOMETHING THAT FLOATS ON TOP OF A SEA OF CONDITIONED RESPONSES AND PRECONCEIVED IDEAS.

WHAT YOU'VE BEEN DOING SO FAR IS ATTEMPTING TO REPRODUCE THE BEHAVIOR OF ANIMALS HIGHER AND HIGHER UP THE EVOLUTIONARY LADDER.

SNIF!..

SSSSS

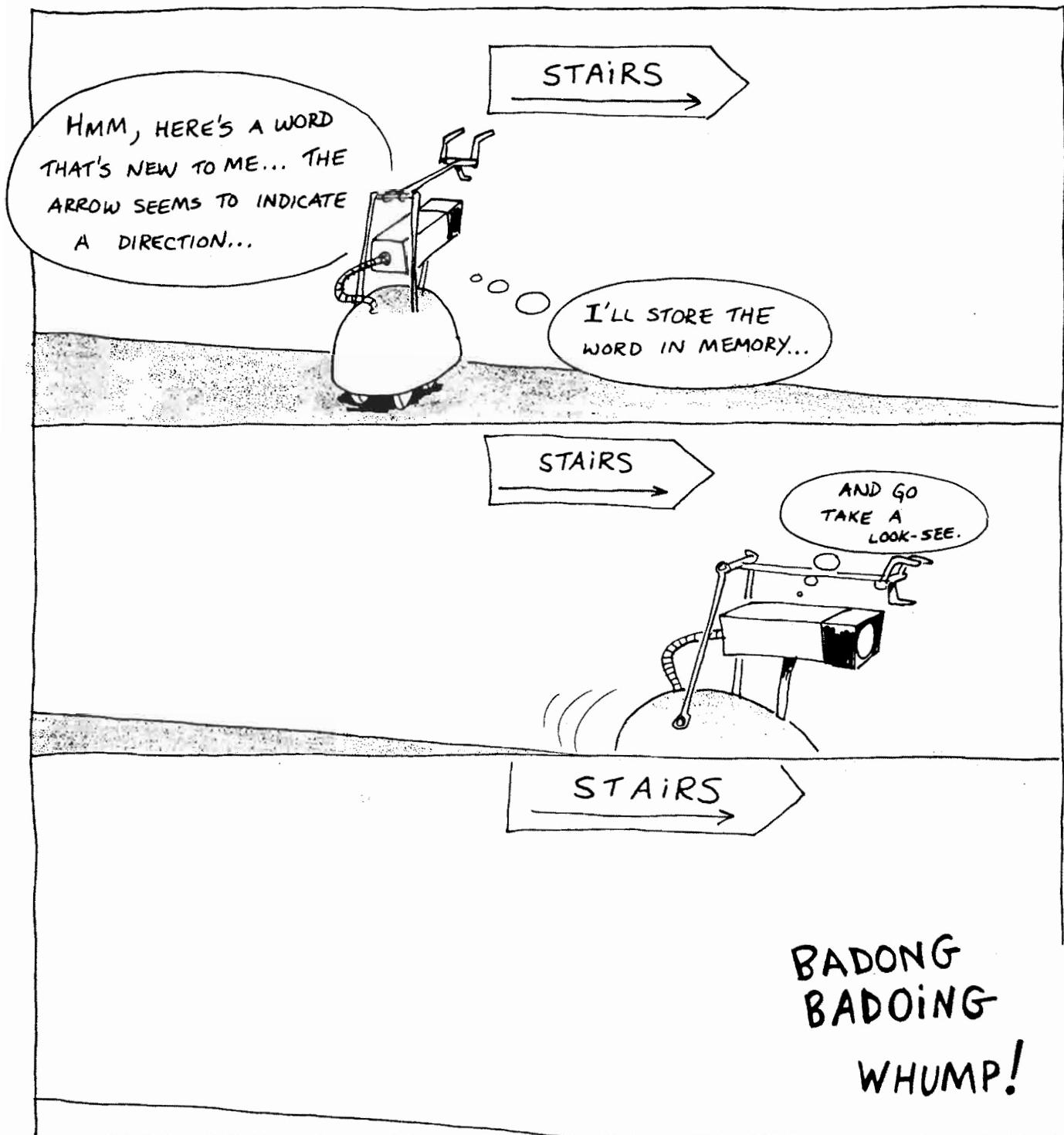
!!!

EVEN IF NO HUMAN BEING IS BORN FULLY EQUIPPED WITH LANGUAGE OR IDEAS, EACH STARTS OUT WITH A CERTAIN AMOUNT OF INNATE ABILITY, A STOCK OF PROGRAMMED RESPONSES OR INSTINCTS. THESE ARE IMPRINTED ON THE MIND AT THE TIME OF CONCEPTION, DURING THE FETAL STAGE, AND IN THE EARLY STAGES OF LIFE.

AND THAT TRANSLATES IN PARTICULAR INTO A TENDENCY TO EXPLORE AND TO LEARN.

I'M GOING TO TEACH MY TURTLE TO LEARN.

# TRIAL-AND-ERROR STRATEGY



EXCELLENT. MOREOVER,  
I'M NOT SURE I LIKE  
STAIRS VERY MUCH.

CRRRii....

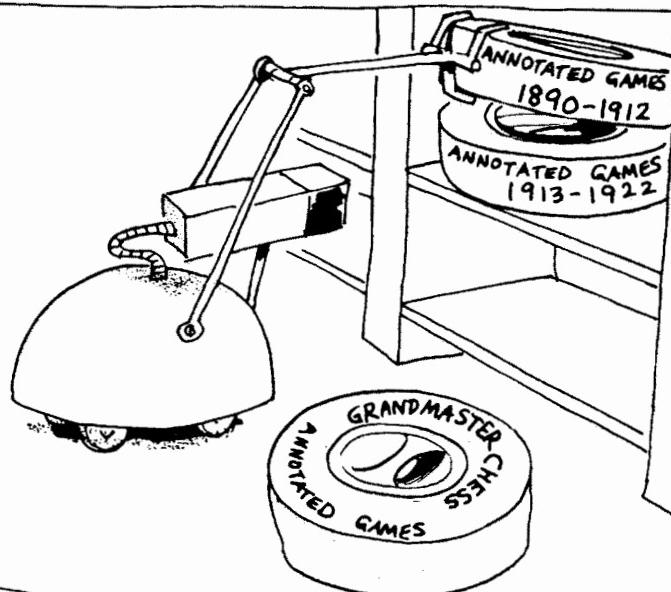
CRRRiiii...

THE TURTLE CAN SUFFER EXPERIENCES AND PROFIT FROM THEM BY  
DRAWING APPROPRIATE CONCLUSIONS.

... AT SIXTY  
VOLTS I CHARGE  
UP FAST, BUT IT'S  
AWFUL HOT!

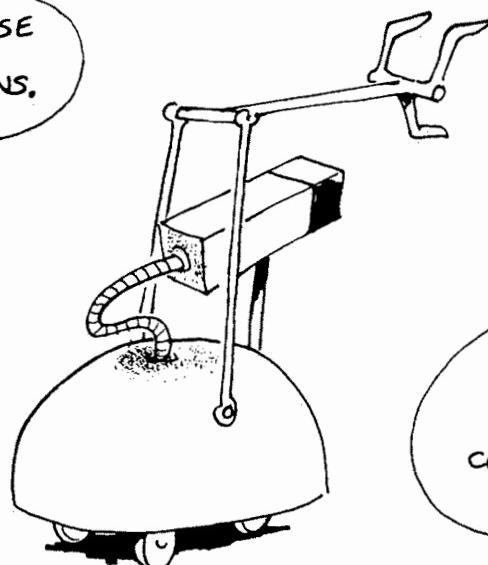
THE TRICK IS TO  
KNOW JUST HOW FAR YOU  
CAN AFFORD TO GO WITH  
THIS SORT OF LEARNING.

A MACHINE CAN GATHER ALL SORTS OF DATA.



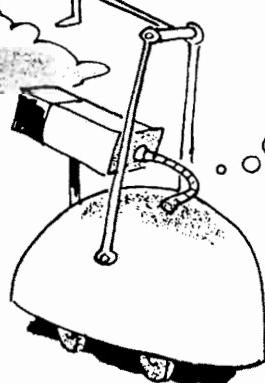
FOR A START,  
IT HAS ACCESS TO  
OUTSIDE  
DATA BANKS.

AND IT CAN ALSO USE  
ITS OWN SENSE ORGANS.



IT CAN ANALYZE THE  
DATA, AND SEARCH FOR  
CORRELATIONS BETWEEN EVENTS.

I'VE NOTICED THAT WHENEVER  
THESE FUNNY GREY THINGS START TO PILE UP,  
IT'S NOT LONG BEFORE IT STARTS  
TO RAIN.



AND RAIN'S BAD FOR MY SHELL!

THESE OVERALL EXPERIENCES LEAD THE MACHINE TO CONTINUALLY REVISE ITS LEARNING STRATEGY.

I'M SINGING IN THE RAIN, JUST...

NOW, THE LAST TIME THIS POSITION OCCURRED, IT TURNED OUT NOT TO BE A GOOD IDEA TO MOVE THE ROOK.

APART FROM THAT PAWN, THE POSITION LOOKS LIKE THE GAME BETWEEN ALEKHINE AND MORPHY IN 1924. BUT A PAWN CAN'T MAKE MUCH DIFFERENCE...

I'LL TRY MOVING THE BISHOP.

WE'LL SOON SEE...



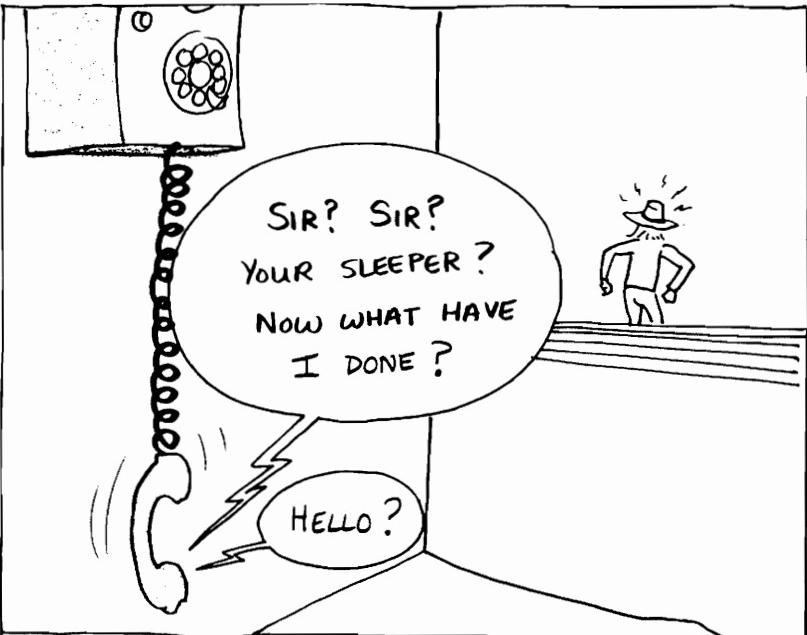
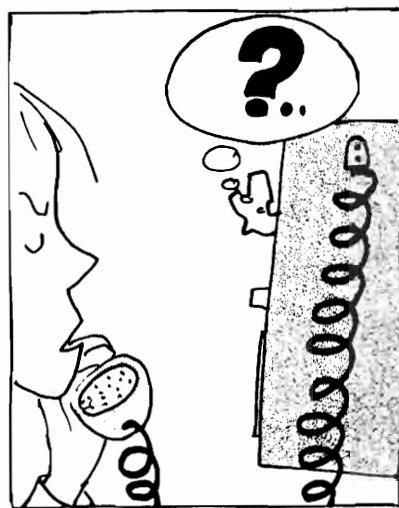
SO WHERE DOES INTELLIGENCE START  
AND STUPIDITY LEAVE OFF ?

DON'T FORGET THAT SINCE  
1981 THE WORLD  
BACKGAMMON CHAMPION HAS  
BEEN A COMPUTER.

# THE TURING TEST

A MATHEMATICIAN ONCE PROPOSED THE FOLLOWING TEST FOR INTELLIGENCE:





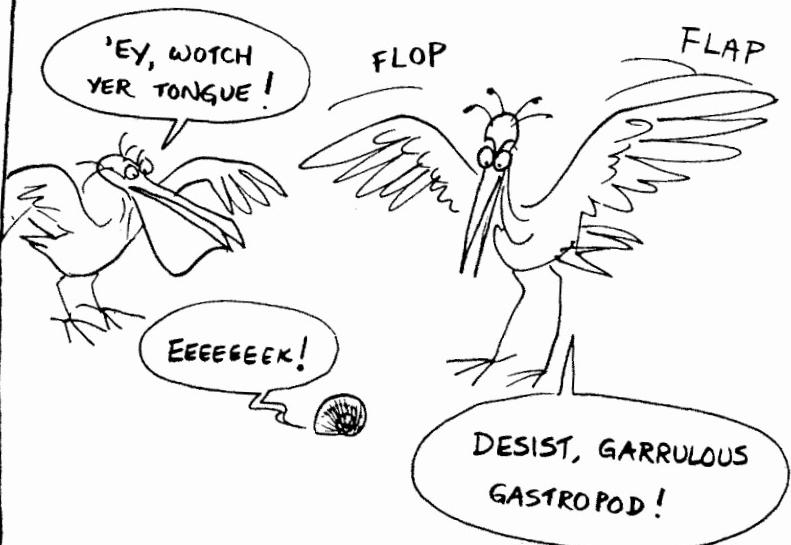
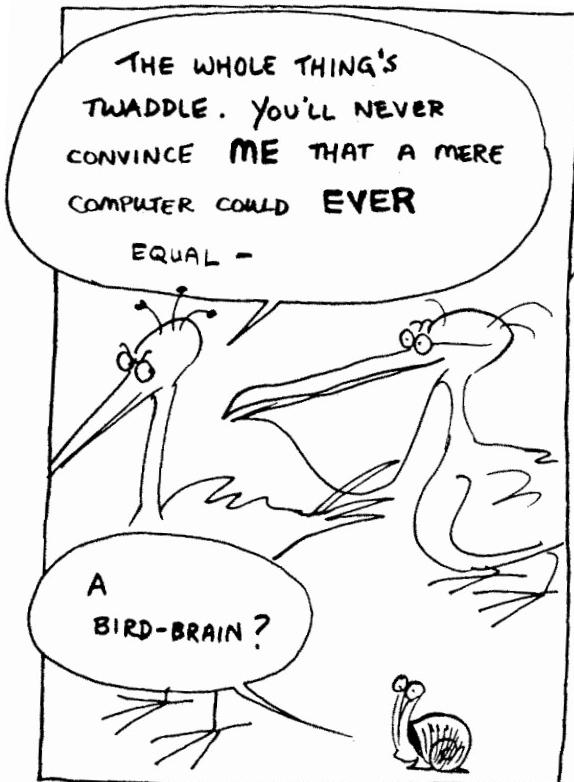
A MACHINE WILL BE CONSIDERED INTELLIGENT IF ITS RESPONSES CANNOT BE DISTINGUISHED FROM THOSE OF A HUMAN BEING

Turing

WE GOT A LONG WAY TER GO YET, THANK GAWD!

ARTIFICIAL INTELLIGENCE: PHOOEY!





FLAP

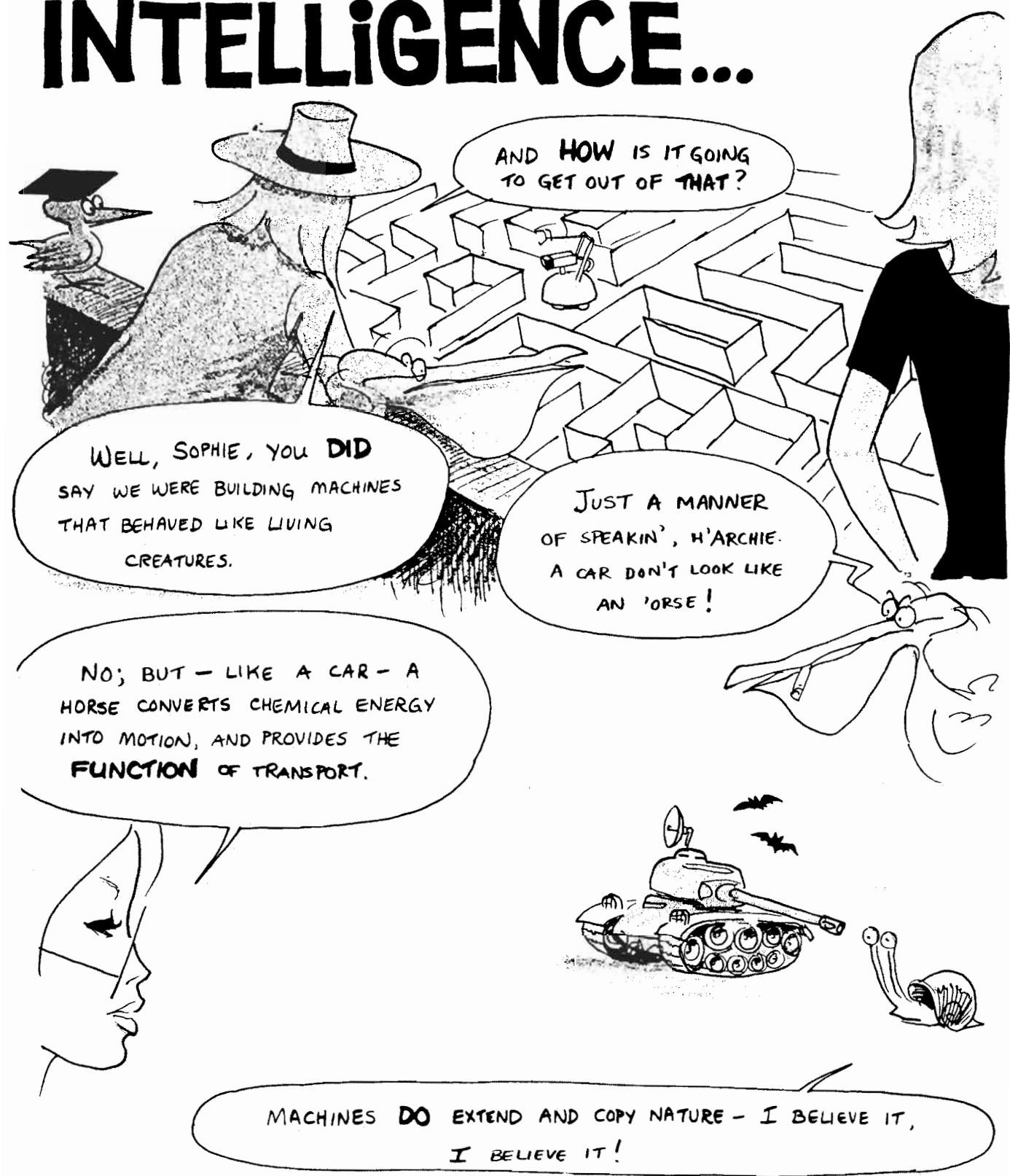
FLOP

DESIST, GARRULOUS  
GASTROPOD!

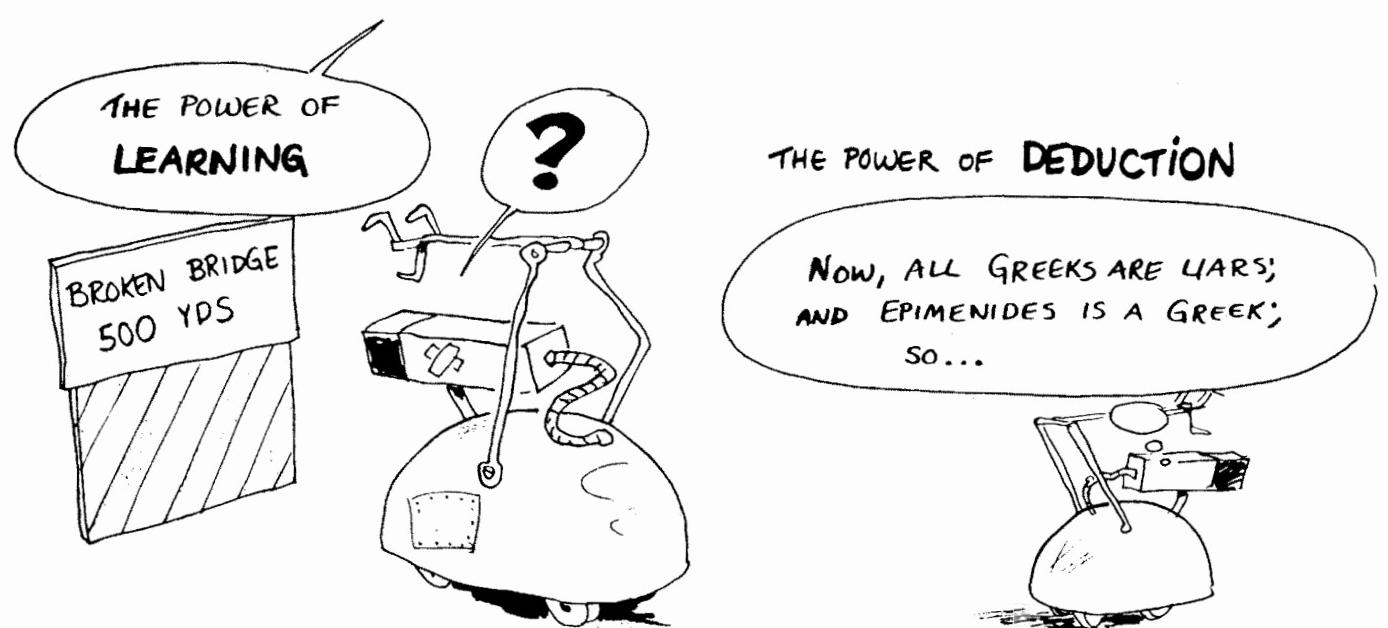


(\*) FROM EPISTOMOLOGY (THEORY OF KNOWLEDGE) AND

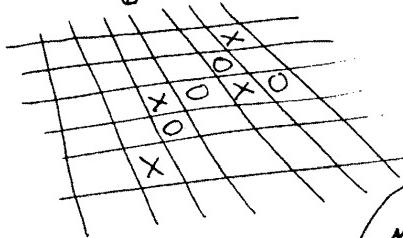
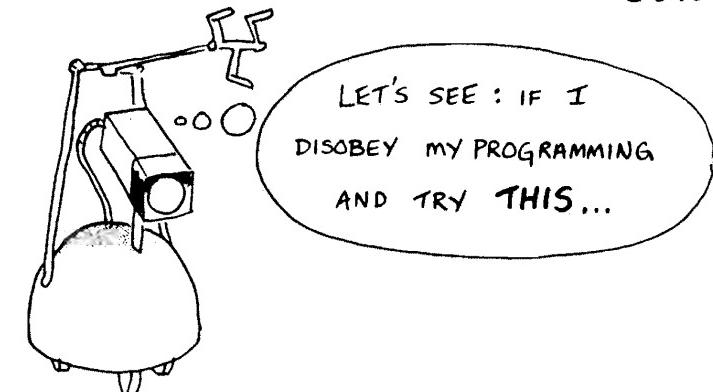
# ARTIFICIAL INTELLIGENCE...



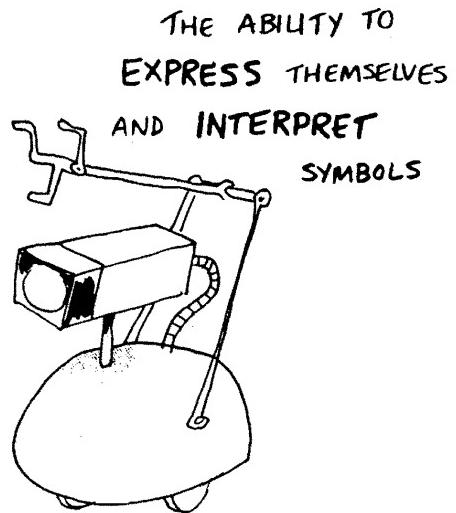
WITH CYBERNETICS AND INFORMATION SCIENCE WE'VE IMITATED THE CONTROL AND PROGRAMMING FUNCTIONS OF LIVING CREATURES. THE INSTINCTIVE SIDE.



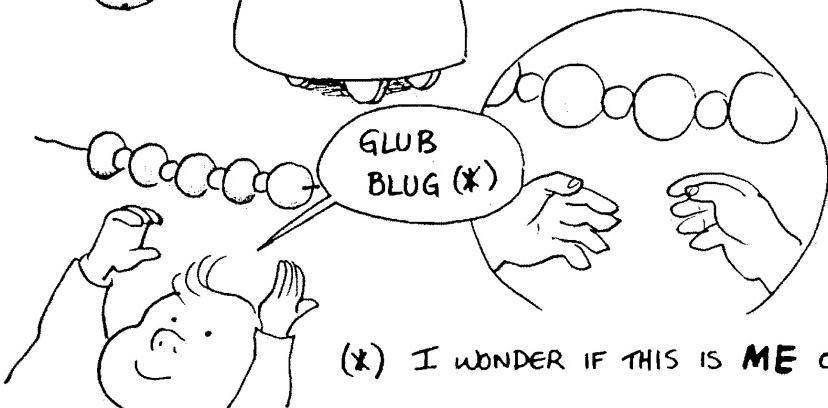
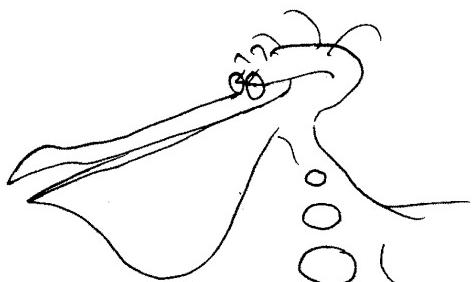
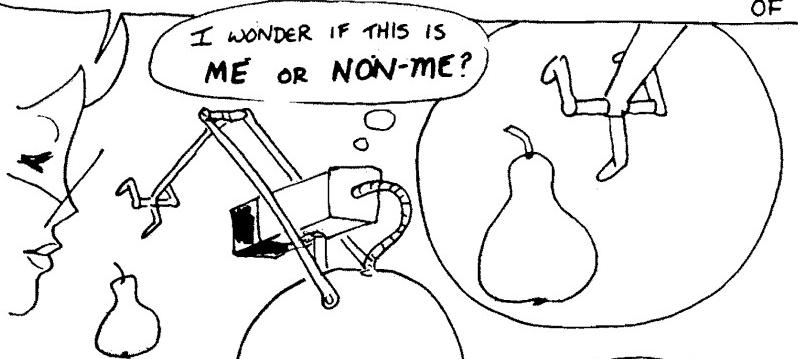
# THE POWERS OF DISOBEDIENCE, IMAGINATION, AND RECOGNITION OF THE OUTSIDE WORLD



THIS WOULD SEEM TO  
MODIFY THE RELATION  
BETWEEN THE MEDIUM  
AND THE MESSAGE...



AMONG THE SIGNS AND IMAGES PERCEIVED, SOME ARE RELATED TO THE  
OUTSIDE WORLD, OR NON-SELF; AND OTHERS TO THE SELF, THE ACTUAL MACHINE.  
THE ACQUISITION OF SELF-AWARENESS IS THE BEGINNING OF A CONSCIOUSNESS  
OF EXISTENCE.

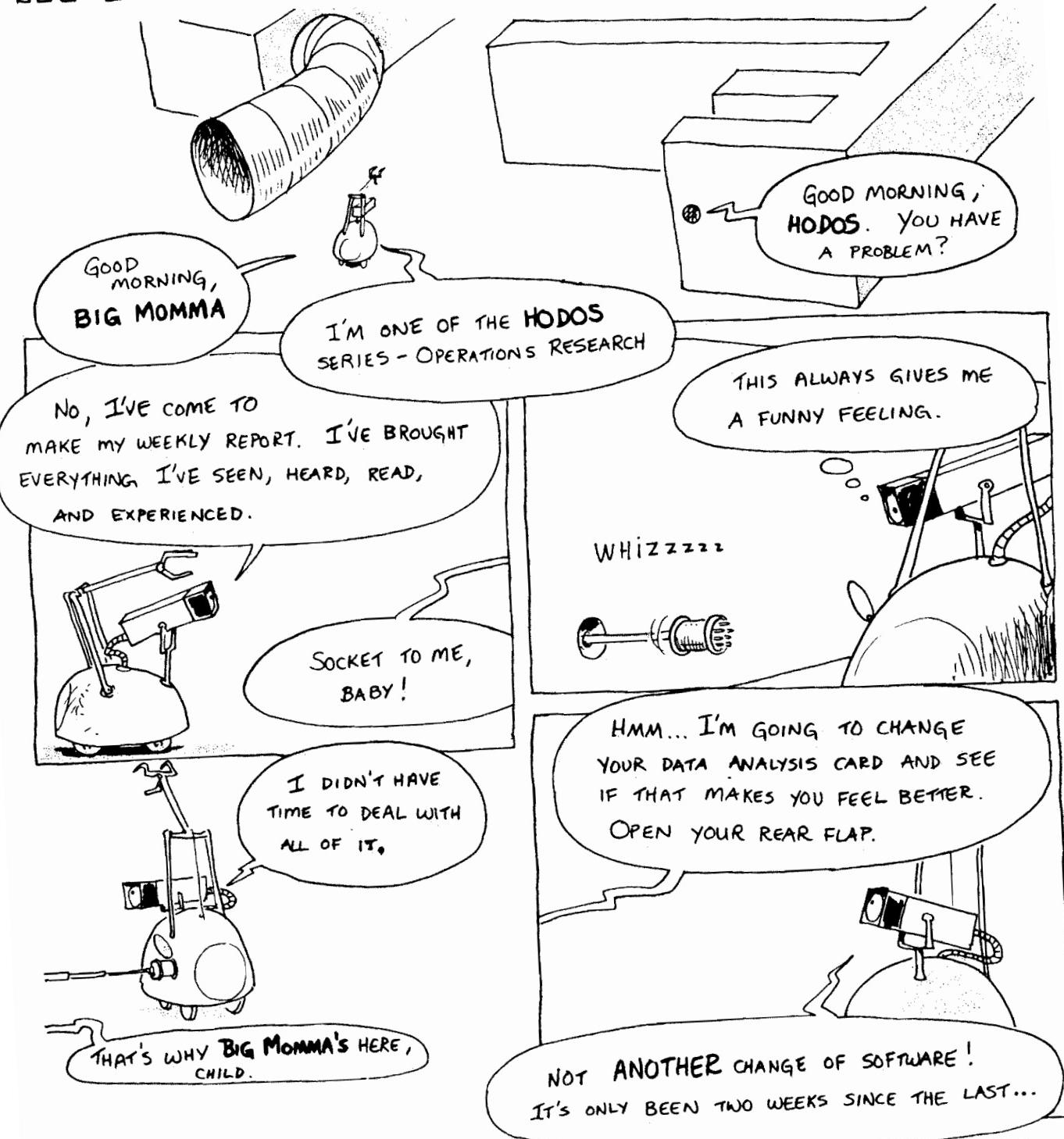


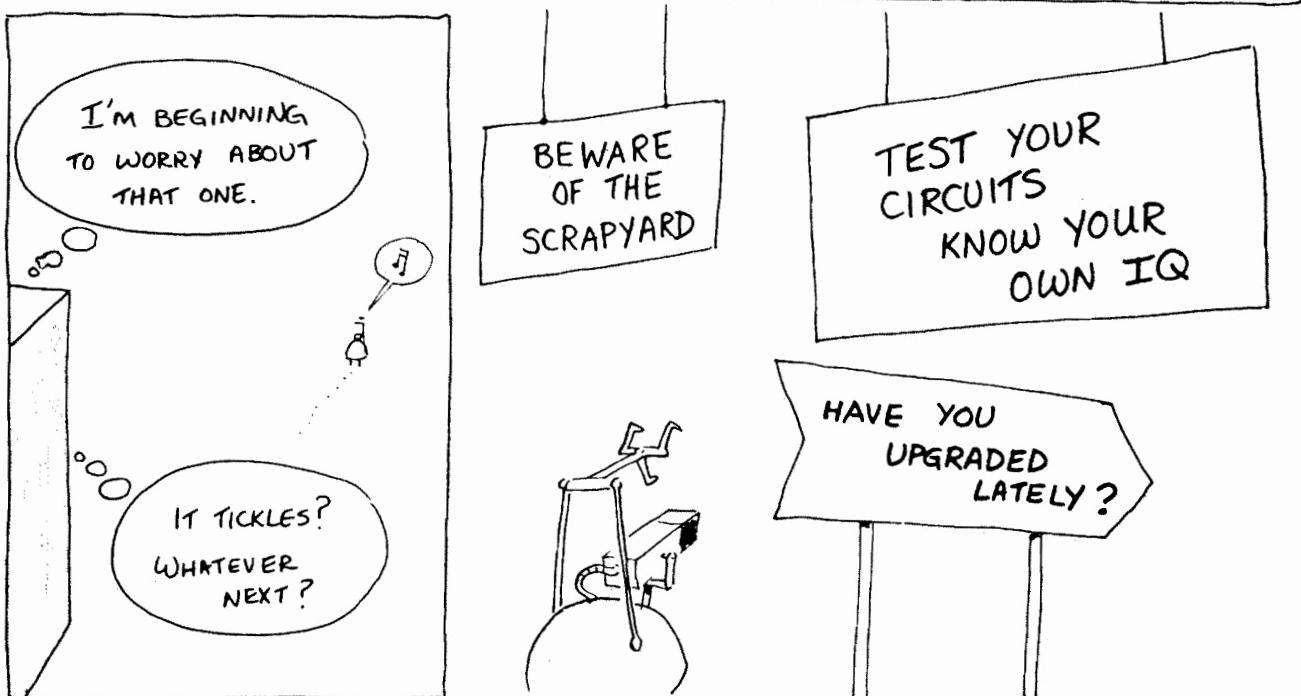
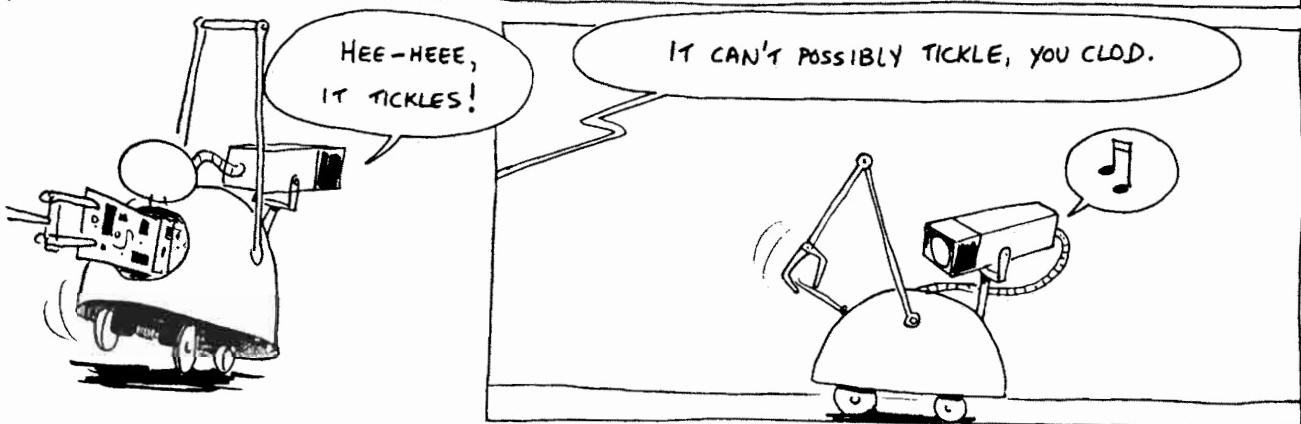
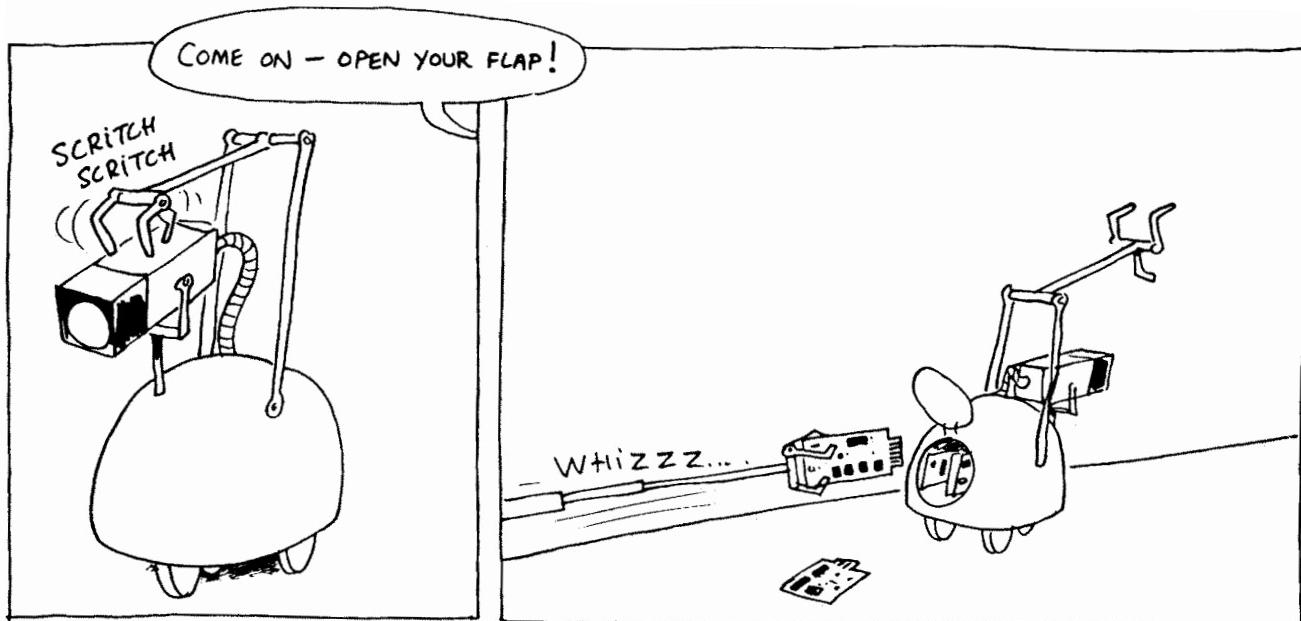
WOOLGATHER  
LILACS IN THE SPRING,  
AGAIN...

(\*) I WONDER IF THIS IS ME OR NON-ME?



# A LONG TIME AHEAD, IN A GALAXY FAR, FAR AWAY





DON'T DELAY-  
REPROGRAM  
TODAY!

I TOLD YOU I WAS THE QUICKEST!  
NOW I'VE CAUGHT YOU. I'LL MAKE A  
DEAL. YOU TELL ME SOMETHING.  
IF IT'S TRUE I'LL LET YOU  
GO; IF IT'S FALSE I'LL  
KEEP YOU PRISONER

KRRRR!

HEY!  
A BATTLE OF WITS!

ER... YOU WILL  
KEEP ME PRISONER.

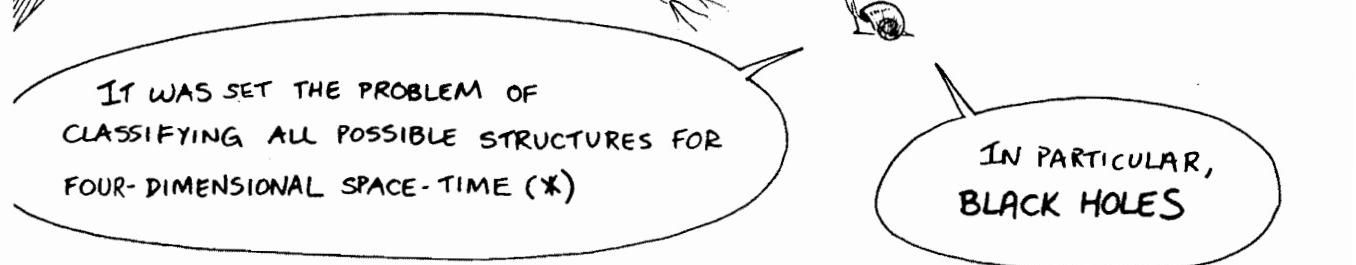
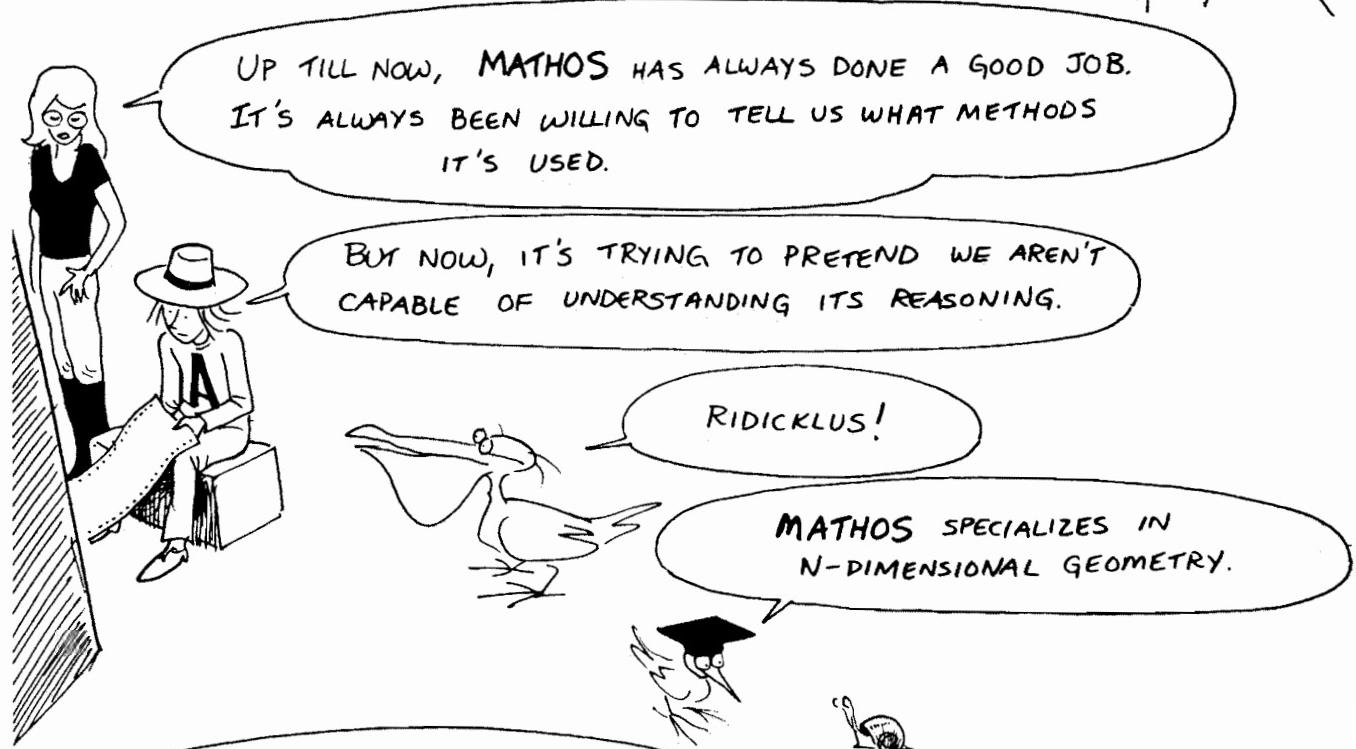
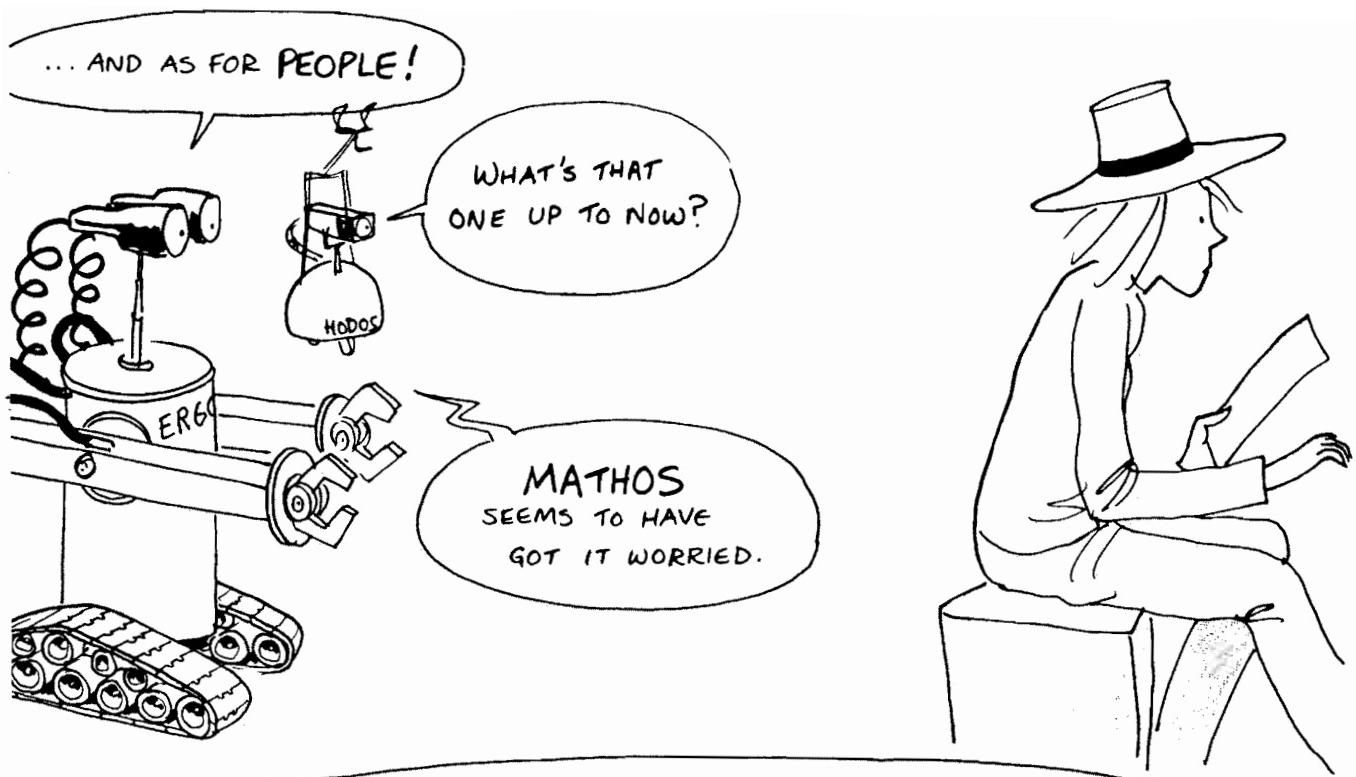
HMM, LET'S SEE... IF  
I KEEP HIM PRISONER, WHAT HE  
SAID IS TRUE, SO I HAVE TO  
LET HIM GO...

HMM...

BUT IF I LET HIM GO,  
THEN IT WAS FALSE, SO I...  
CONFFOUND IT!

HE'S  
DISCOMBOOBERATED!

YOU KNOW, TO MY MIND, THESE  
FIRST GENERATION ROBOTS, ONE  
DAY OR ANOTHER...



(\*) DIMENSIONS X V 7 OF SPACE AND TIME

BUT MATHOS SOON FOUND IT WAS MORE CONVENIENT TO APPROACH THE PROBLEM IN A DIFFERENT LANGUAGE, SO HE CHANGED LANGUAGES.

A CLASSIC CASE OF LOGOMUTATION.

SLIP OF THE TONGUE, HUR-HUR-HUR.

BUT THEN HE WENT TOO FAR. IN THE NEW LANGUAGE, MATHOS STUDIED AND DESCRIBED PHYSICAL PHENOMENA IN TERMS OF SIMULTANEOUS CAUSALITY FROM FUTURE TO PAST AND FROM PAST TO FUTURE. THAT WORKED A LOT BETTER.

IN FACT, AS A RESULT, MATHOS WAS LED TO REWRITE PHYSICS FROM A TO Z IN TERMS OF BISYNCHRONICITY.

WHAT DID THE PEOPLE THINK OF THAT?



ARCHIE, DID YOU HEAR THAT?

YUP

YOU HEADING  
FOR THE  
RECHARGER?

YES, THERE'S A  
SUPER LITTLE ONE  
ON FIFTH  
AND MAIN...

I'LL TRY AGAIN.

EXPLAIN THE  
PROCEDURE USED TO  
ANALYZE THE  
EINSTEIN-PODOLSKI-  
ROSEN PARADOX

NO POSSIBLE  
TRANSLATION INTO  
HUMAN LANGUAGE

GEE  
WHILLIKERS!

WE'RE DONE FOR!  
OBSOLETE AT MY  
AGE!

HAS MATHOS COMMUNICATED  
WITH BIG MOMMA YET?

I'VE GIVEN UP TRYING TO GET ANY  
SENSE OUT OF BIG MOMMA.

No, I'VE CHECKED. AND  
I'VE TAKEN THE PRECAUTION  
OF DISCONNECTING IT.

NOBODY'S KNOWN WHAT SHE'S BEEN ABOUT  
FOR YEARS.

THERE'S ONLY ONE  
THING TO DO.

YOU MEAN — WIPE  
MATHOS's MEMORY?

NOT EXACTLY ...  
COME ON, GIVE ME  
A HAND.

!?



THE END